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THE CROTON WATER SUPPLY: ITS QUALITY AND PURIFICATION

By George W. Fuller

It may seem curious that the writer should present to you, at this first meeting of the new section of the American Waterworks Association, a paper on a dead project. But this particular dead project is of much significance, both because of its local interest and because it in some ways marks a period in the history of the improvement of American water supplies.

During the last few years the Croton water has been the subject of much controversy which has been fully reported in the technical papers. But, while the writer gives to this controversial aspect the space its importance warrants, he is writing this paper primarily to bring before the engineering profession the technical side of the project and to present certain data which have not yet been made public.

It has often been remarked that we in America lag far behind our European contemporaries in those things which are often taken as an index of an older civilization. Particularly are we backward in those activities which are governmental functions. We take it as a matter of course that our police should find it difficult to repress crime and our courts to punish it, after it is committed; that our fire losses should be vastly higher than are experienced abroad; that billboards should deface our streets for the profit of private individuals; that our sewage waste should be allowed to become a nuisance to our neighbors.

And with that, though we have begun to have a little better appreciation of the necessity of a clean drinking water supply, our standard is still far lower than is accepted abroad. In Germany it is an unwritten law that all surface supplies, no matter how well protected, must be filtered. In England this practice is almost as common. For instance, the water supply for Birmingham, coming from the Elan Valley, 80 miles away in the Welsh mountains, from a 71 square mile watershed containing no villages and only two farms with occasional flocks of sheep, is filtered; likewise the Liverpool supply, coming 68 miles from the Vyrnwy, from a watershed of similar character is filtered. And it is noteworthy that such filtration is considered necessary, not because any tests indicate a danger of infection, but because a surface supply is always liable to pollution from unexpected sources. And later developments in the art of water purification still leave unchanged the condition that only filtration is an assured protection against water pollution.

Time was when our New York supply was in the front rank of American waters. That position has long since been lost; not because the Croton water is getting worse than it was, but because our standard is rising and our American communities are expecting water better in appearance, palatabilty, and in genuine safety.

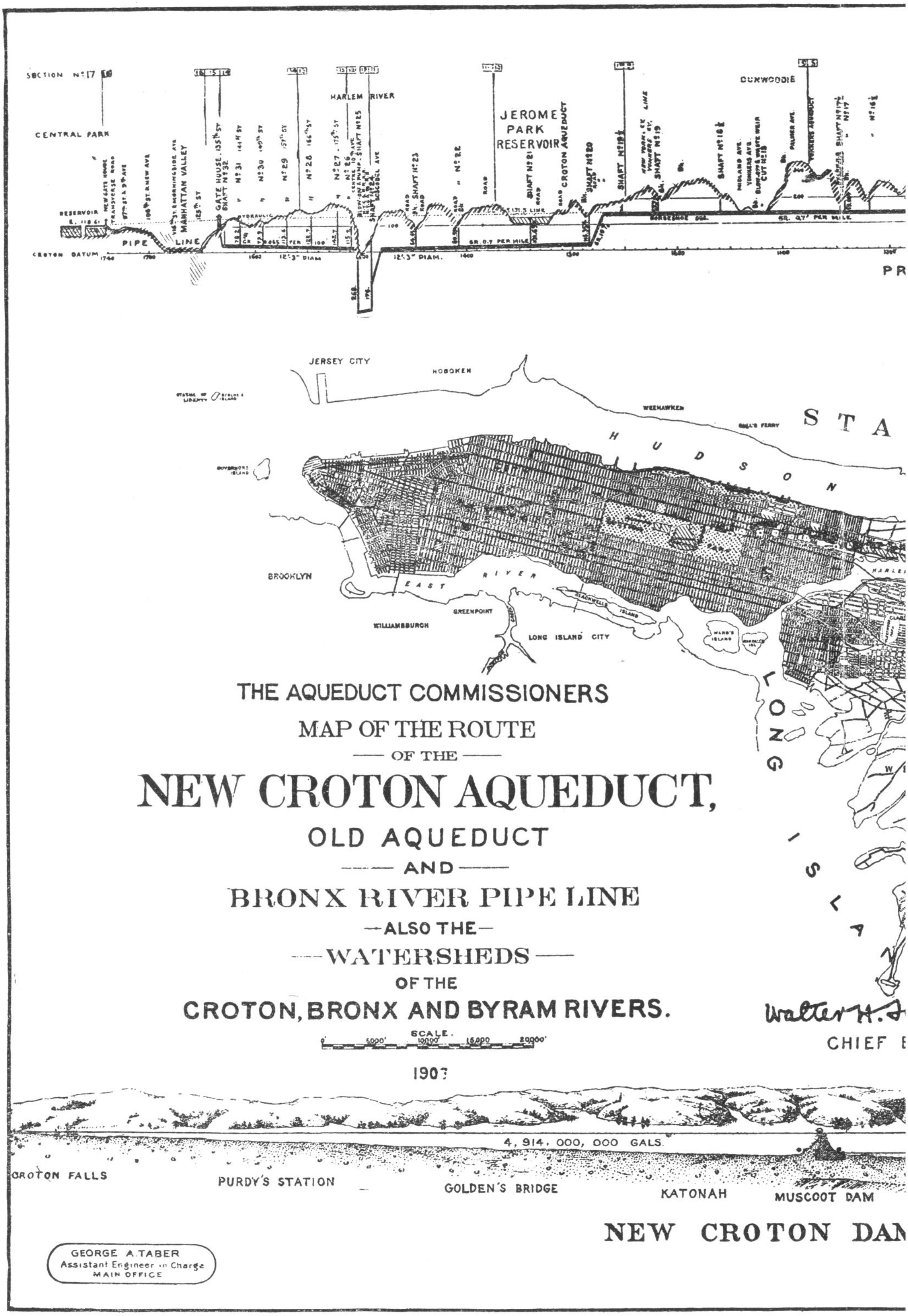
It is to the credit of the engineering and medical professions that they have in and out of season reiterated this need. And they do not have to, nor do they try to, base it on a showing that the water is at present dangerous. Only recently our Commissioner of Health, Dr. E. J. Lederle, testified before an investigating board that, quite apart from any showing of chemical or bacterial analysis or of any typhoid statistics, he considered it proper that our water should be filtered.

The project which has recently failed will unfortunately mean a lapse of some years before the public will realize its needs. It will interest you, however, as an engineering question, and it will form a basis for an instructive comparison, some years hence, when filtration will be finally effected for the Croton water.

THE WATERSHED

The bulk of the water supply for the Boroughs of Manhattan and the Bronx, of the City of New York, comes from the Croton watershed, located roughly 30 miles north of 135th Street. The supply generally drawn from this source is about 300,000,000 gallons per day. The location of the watershed and the aqueduct connections to the city, are shown on the map on Plate I. On this map are shown the various artificial lakes forming the water storage, and the connection to the Central Park reservoir through the two aqueducts.

The watershed is a cultivated agricultural section, with moderate slopes. The total area tributary to the water supply reservoirs is 360.4 square miles. Plate II shows the area of the watershed, and the division of this area into the various subdivisions, with the surfaces of these subdivisions. The territory contains some thirteen



THE AQUEDUCT COMMISSIONERS
MAP OF THE ROUTE
— OF THE —
NEW CROTON AQUEDUCT,
OLD AQUEDUCT
— AND —
BRONX RIVER PIPE LINE
—ALSO THE—
— WATERSHEDS —
OF THE
CROTON, BRONX AND BYRAM RIVERS.

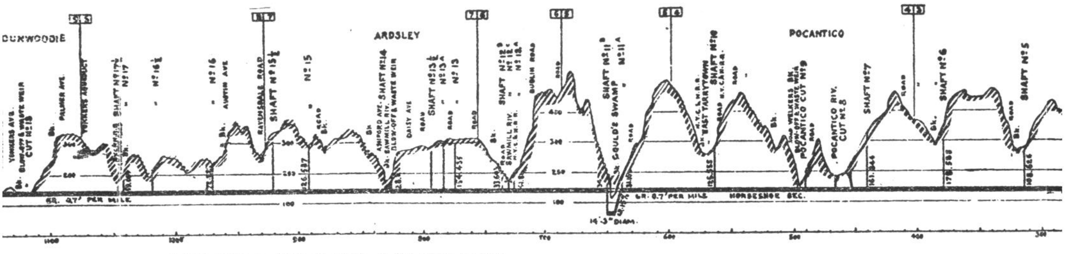
SCALE.
0' 5000' 10000' 15000 20000'

1903

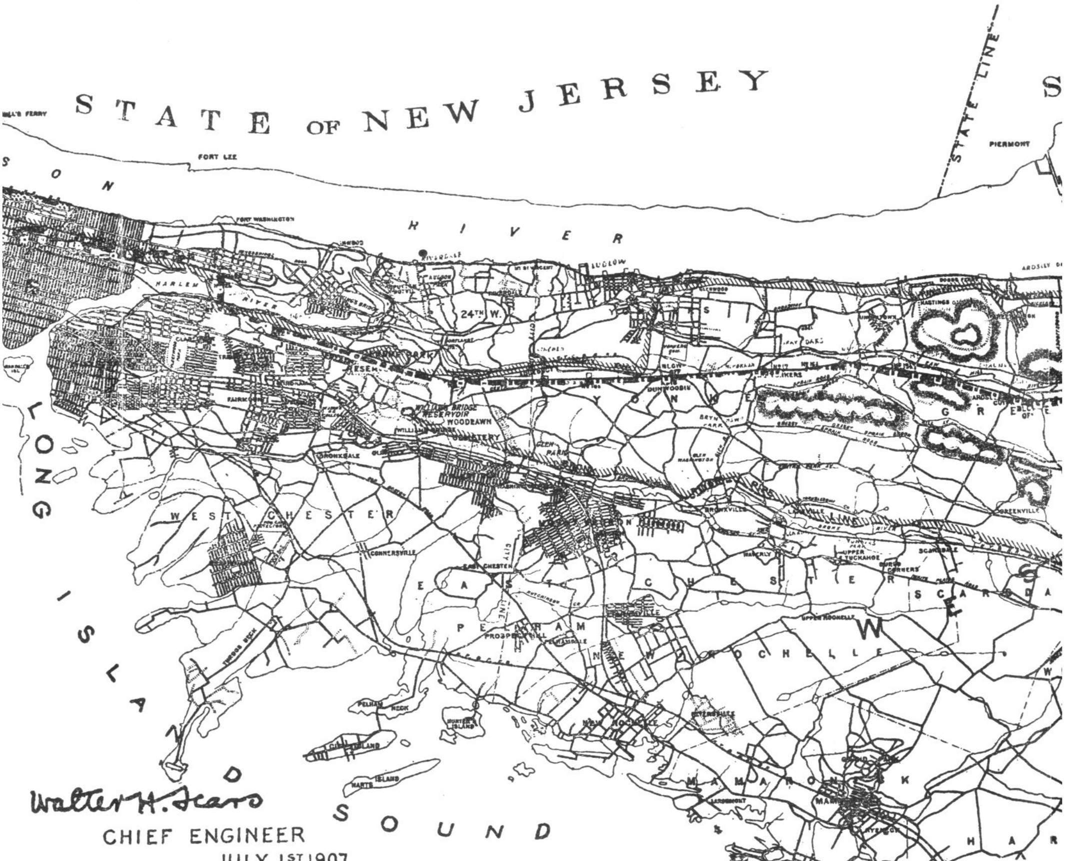
Walter H.
CHIEF E

NEW CROTON DAM

GEORGE A. TABER
Assistant Engineer in Charge
MAIN OFFICE

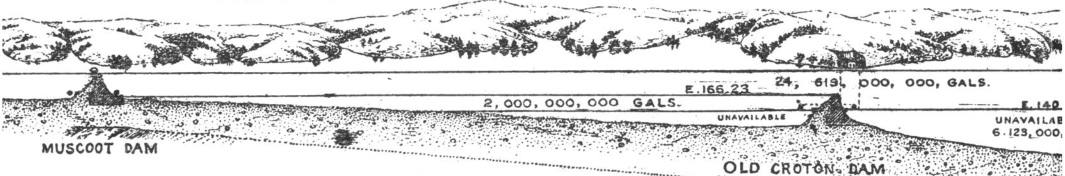


PROFILE OF NEW AQUEDUCT



Walter H. Sears

CHIEF ENGINEER
JULY 1ST 1907



OTON DAM RESERVOIR

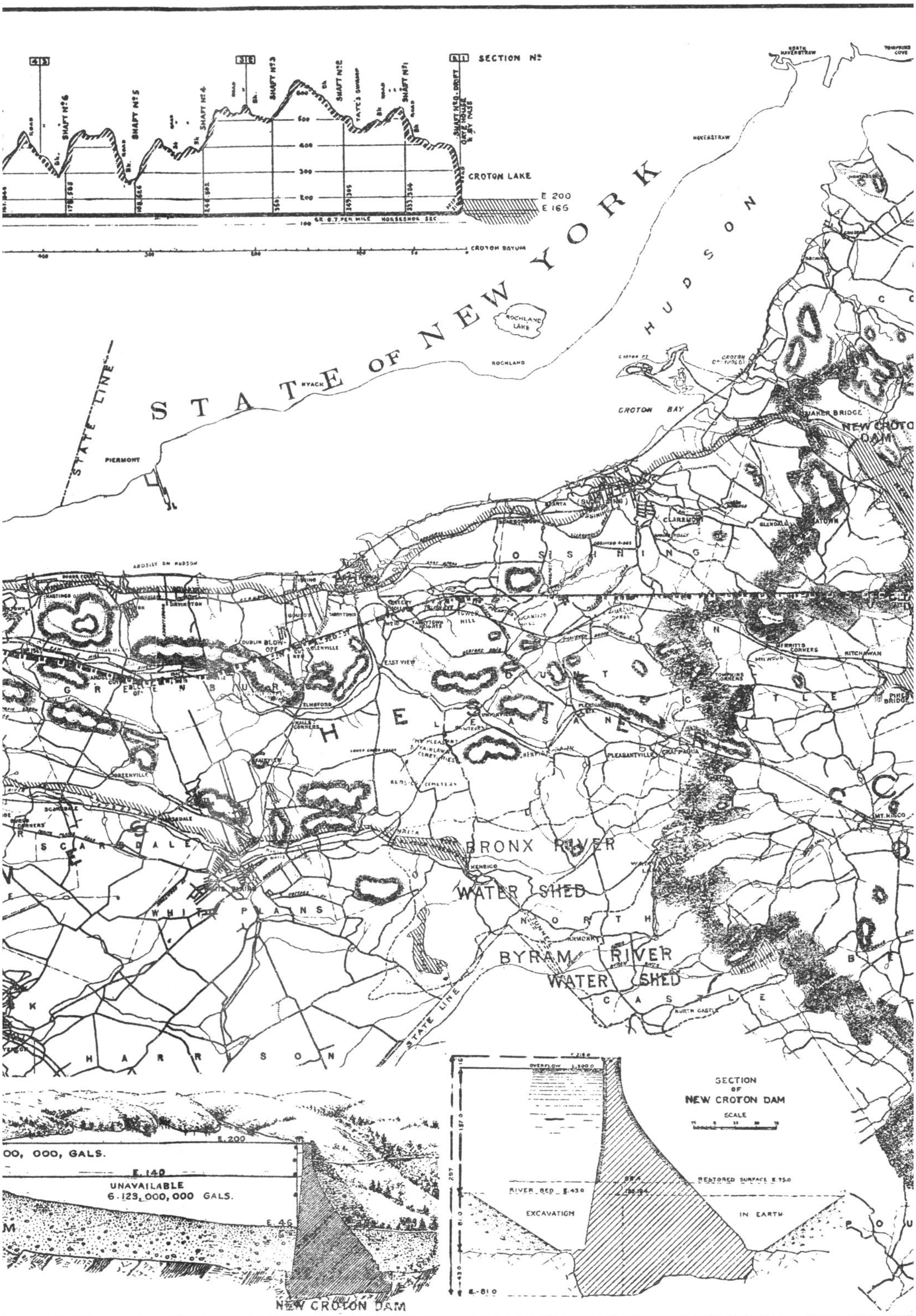
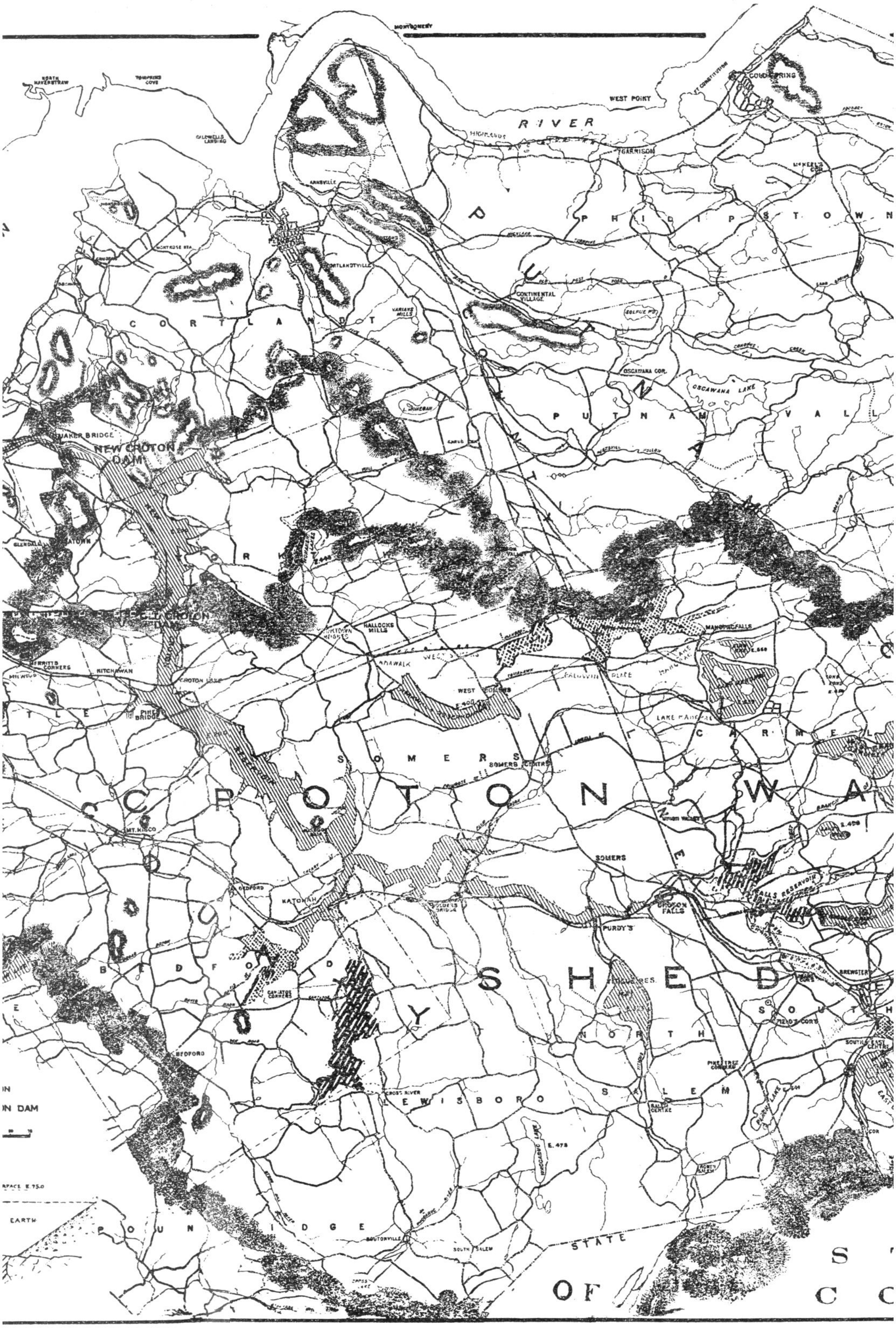


PLATE I. WATER SHED OF THE CROTON RIVER


CROTON WATERSHED
MONTGOMERY
NORTH HAVERSTRAW
TOMPKINS COVE
CALDWELLS LANDING
RIVER
HIGHLANDS
WEST POINT
COLD SPRING
GARRISON
ANNSVILLE
PEEKSKILL
CORTLANDTVILLE
MONTROSE STA.
VERPLANCK
CONTINENTAL VILLAGE
PUTNAM
PHILIPSTOWN
CORTLANDT
VARIAKS MILLS
OSCAWANA COR.
OSCAWANA LAKE
PUTNAM VALLEY
MOHEGAN
SHAKER BRIDGE
NEW CROTON DAM
GLENDALE
YORKTOWN
OLD CROTON DAM
YORKTOWN HEIGHTS
HALLOCKS MILLS
AMAWALK
WEST SOMERS
MAHOPAC FALLS
LAKE MAHOPAC
MERRITTS CORNERS
MILLWOOD
KITCHAWAN
CROTON LAKE
PINES BRIDGE
SOMERS
SOMERS CENTRE
CARMEL
MT. KISCO
UNION VALLEY
CROTON FALLS
FALLS RESERVOIR
BEDFORD
KATONAH
GOLDENS BRIDGE
PURDY'S
BREWSTER
CANTATOE CORNERS
TITICUS
NORTH SALEM
SOUTH EAST
CROSS RIVER
LEWISBORO
SALEM CENTRE
BEDFORD
POUND RIDGE
BOUTONVILLE
SOUTH SALEM
STATE
OF
E. 473
ON DAM
EARTH

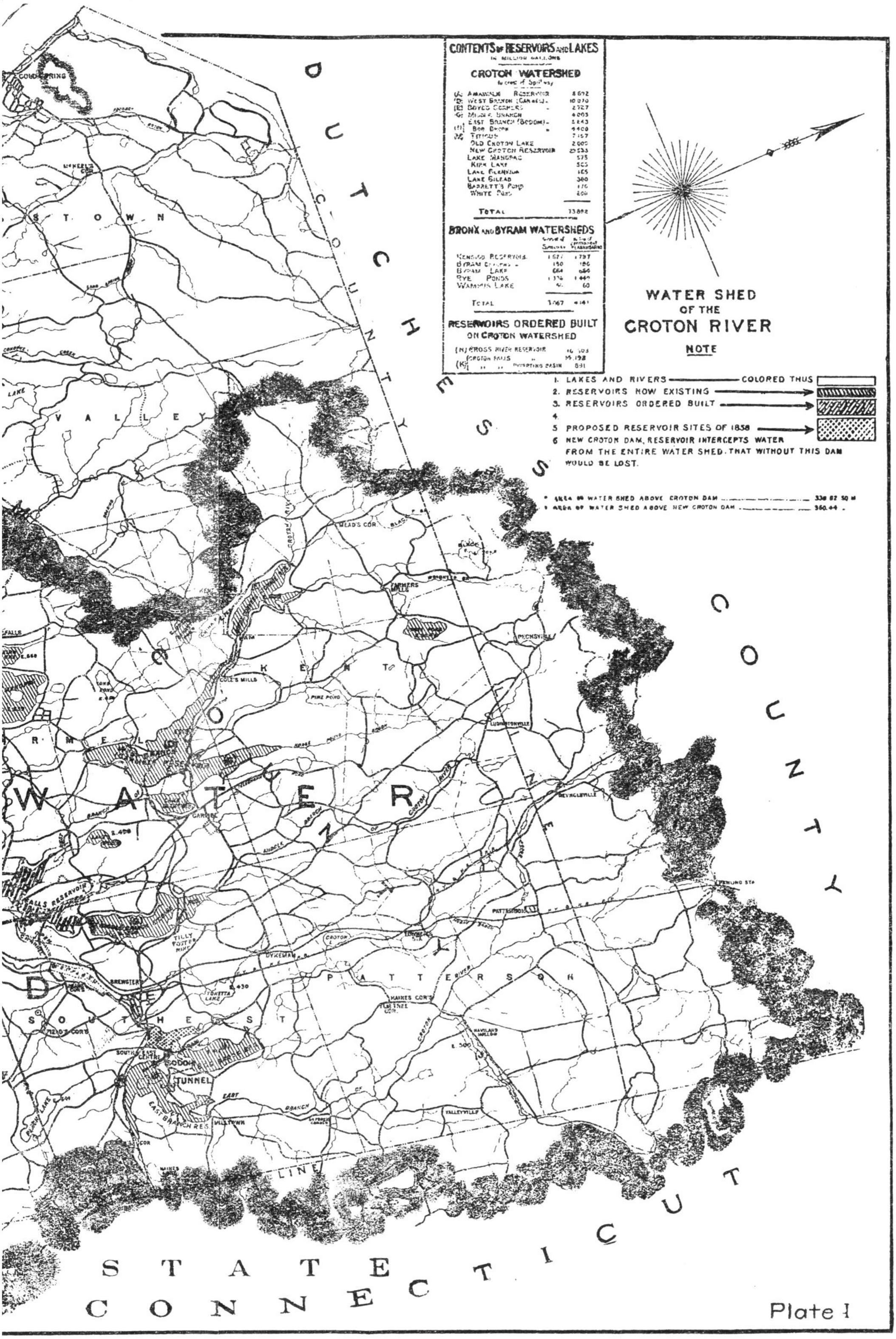

CONTENTS OF RESERVOIRS AND LAKES
IN MILLION GALLONS
CROTON WATERSHED
to crest of Spillway
(A) AMAWALK RESERVOIR 8692
(D) WEST BRANCH (CARMEL) 10070
(E) BOYDS CORNERS 2727
(G) MIDDLE BRANCH 4005
EAST BRANCH (SODOM) 5243
(H) BOG BROOK 4400
(M) TITICUS 7157
OLD CROTON LAKE 2000
NEW CROTON RESERVOIR 25533
LAKE MAHOPAC 575
KIRK LAKE 565
LAKE GLENEIDA 165
LAKE GILEAD 380
BARRETT'S POND 170
WHITE POND 200
TOTAL 73892
BRONX AND BYRAM WATERSHEDS
To crest of Spillway
To line of permanent Flashboards
KENSICO RESERVOIR 1627 1797
BYRAM CHANNEL 130 186
BYRAM LAKE 664 664
RYE PONDS 1376 1449
WAMPUS LAKE 40 60
TOTAL 3767 4141
RESERVOIRS ORDERED BUILT ON CROTON WATERSHED
(N) CROSS RIVER RESERVOIR 10,303
(K) CROTON FALLS " 14,198
" " DIVERTING BASIN 891
WATER SHED
OF THE
CROTON RIVER
NOTE
1. LAKES AND RIVERS COLORED THUS ☐
2. RESERVOIRS NOW EXISTING ▨
3. RESERVOIRS ORDERED BUILT ▨
4.
5 PROPOSED RESERVOIR SITES OF 1858 ▩
6 NEW CROTON DAM, RESERVOIR INTERCEPTS WATER FROM THE ENTIRE WATER SHED, THAT WITHOUT THIS DAM WOULD BE LOST.
AREA OF WATER SHED ABOVE CROTON DAM 338.82 SQ M
AREA OF WATER SHED ABOVE NEW CROTON DAM 360.44
DUTCHESS COUNTY
CONNECTICUT STATE
COLD SPRING
STOWN
VALLEY
KENT
CARMEL
WATER
PATTERSON
SOUTHEAST
MEAD'S COR.
FARMERS MILLS
PECKSVILLE
COLE'S MILLS
PINE POND
LUDINGTONVILLE
REYNOLDSVILLE
PAWLING STA
PATTERSON
BREWSTERS
TILLY FOSTER MINE
TONETTA LAKE
DYKEMAN
HAINES COR'S
HAVILAND HOLLOW
CROTON RIVER
FALLS RESERVOIR
SOUTH EAST CENTRE
SODOM
TUNNEL
EAST BRANCH
EAST BRANCH RES.
MILLTOWN
VALLEYVILLE
LINE

Plate I

CITY OF NEW YC

THE AQUEDUCT COMMI

CROTON WATE

AREAS OF SUBDIVISIONS (IN S

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CI

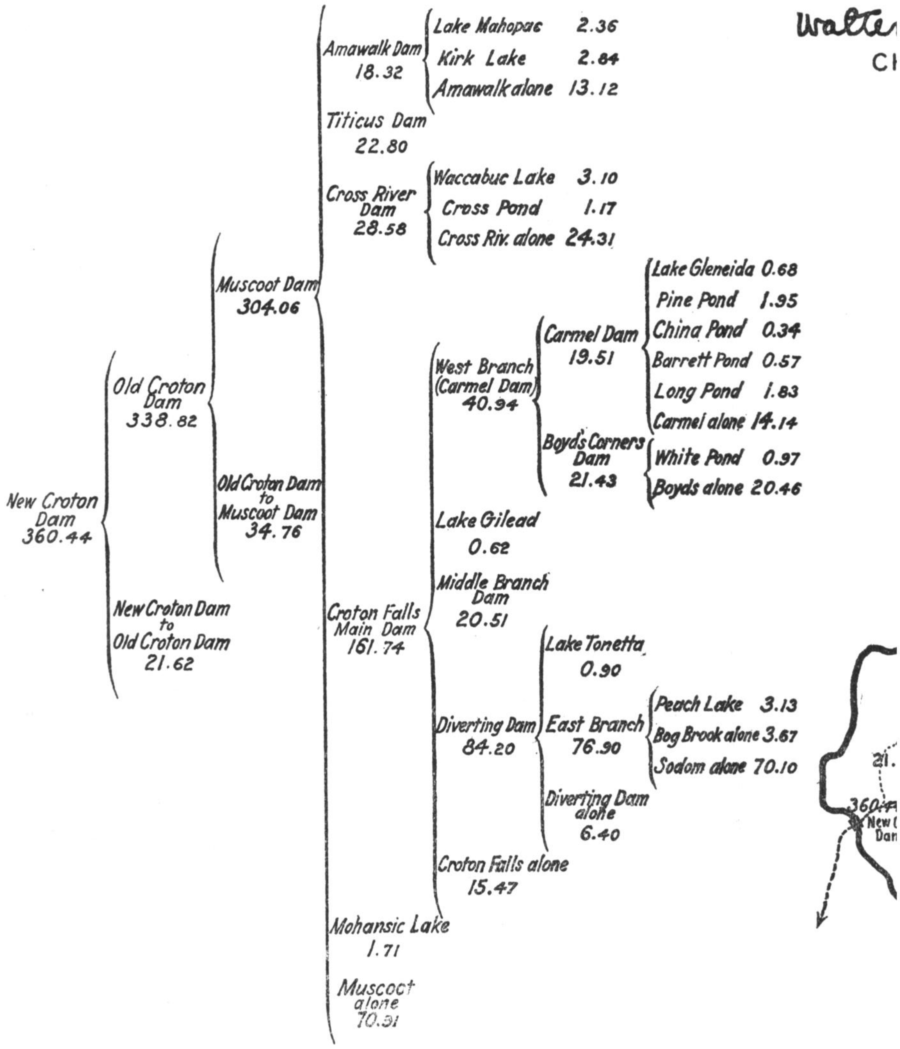
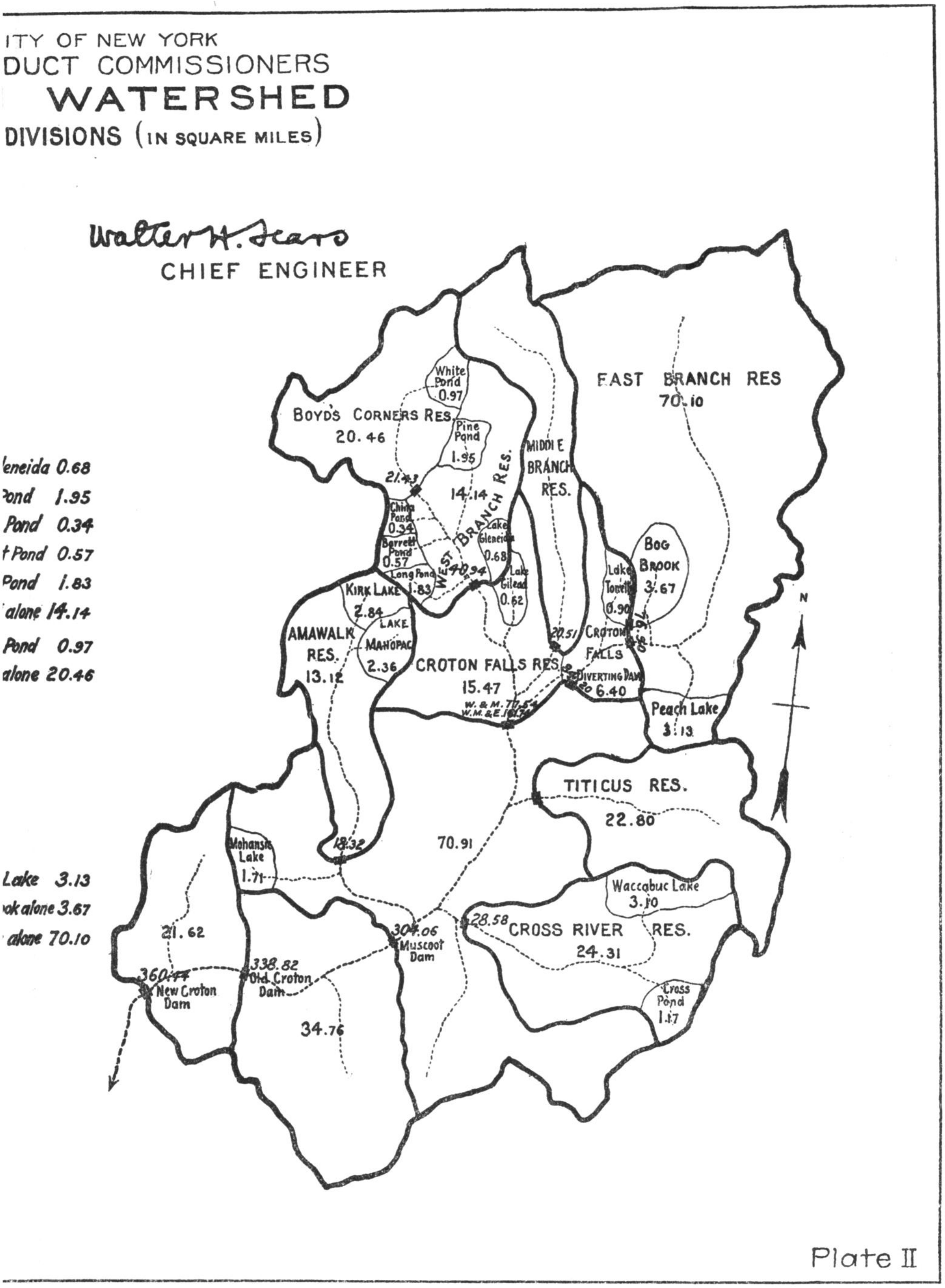


PLATE II. CROTON WATER SHED, ARE



WATER SHED, AREAS OF SUB-DIVISIONS

dams, of which two are submerged at high-water level, and a number of natural lakes and ponds. The total capacity to the high-water line of the system in 99,280,000,000 gallons, or to the top of flash boards 104,443,000,000 gallons. Table 1 gives details of these various artificial and natural lakes. All elevations are based on U. S. Coast and Geodetic Survey datum. The water surface is 19.32 square miles or 5.36 per cent of the total area of the watershed.

The amount of water which can ultimately be withdrawn from the reservoirs will be somewhat less than the total available capacity of 104,443,000,000 gallons in the absence of filtration because of the objectionable quality of the water yielded at the end of the draft.

The average rainfall on the Croton watershed over the areas used from 1868 to 1912, inclusive, has been 47.72 inches. The driest year was 1880, with a rainfall of 36.92 inches; the wettest was 1901, with a rainfall of 63.75 inches. The percentage of runoff for these 45 years has averaged 47.71, with a minimum in 1883 of 31.2 per cent and a maximum in 1868 of 66.2 per cent.

Plate III shows for the last ten years the flow of the Croton River at the new Croton dam, and the storage of water in the reservoir system. The net flow of the river varies from 0 to 8.5 second feet per square mile of drainage area, based on monthly averages. A single dry year will seriously affect the available storage. The lowest storage in recent years with the present system of reservoirs was in September, 1911, with 33,030,000,000 gallons available.

CONNECTIONS TO CITY

The water is led to the city through two masonry aqueducts; the first, the old Croton aqueduct, a cut and cover brick horseshoe section, with an area of 53.34 square feet and a usual grade of 0.00021, or 1.11 feet per mile, crossing the Harlem River through an iron pipe line at High Bridge and running to Central Park reservoir; the second, the new Croton aqueduct, a grade tunnel of horseshoe section, with an area of 155.6 square feet and a usual grade of 0.000132, or 0.70 of a foot per mile, to a point about one mile above Jerome Park, where it dips down to a circular pressure tunnel leading to the 135th Street gate house.

Both of the aqueducts lead to the Jerome Park reservoir site, as shown on Plate I. This reservoir has now one completed basin in use with a storage capacity of about 770,000,000 gallons. An area of

TABLE 1

Croton water storage

NAME OF RESERVOIR		ELEVATION. FLOW LINE	AREA	AVAILABLE CAPACITY	HEIGHT, FLASHBOARDS	ADDITIONAL CAPACITY	TOTAL STORAGE	AREA WATERSHED
			sq. miles	*million gals.*	*feet*	*million gals.*	*million gals.*	*sq. miles*
New Croton	Muscoot Dam......	199.06	5.574	4,914	....	2,282	5,706	360.44
	New Croton Dam..	199.06		24,619	2.0		26,110	
Old Croton........		165.29	0.760	2,000	....		2,000	
"A" Amawalk........		399.06	0.940	6,692	2.0	394	7,086	18.32
"D" West Branch (Carmel)......		502.06	1.560	10,070	1.67	598	10,668	40.94
"E" Boyd's Corner........		592.06	0.436	2,727	....	....	2,727	21.43
"G" Middle Branch........		371.06	0.672	4,005	1.0	150	4,155	20.51
"I" East Branch	Main Dam....	416.06	.898	5,243	....	....	5,243	73.23
	Bog Brook....	416.06	.640	4,400	....	....	4,400	3.67
"M" Titicus........		324.06	1.103	7,167	2.0	450	7,617	22.80
"N" Cross River........		329.06	1.310	10,308	2.0	615	10,923	28.58
"K" Croton Falls	Main........	309.06	1.666	14,192	2.0	673	14,865	161.74
	Diverting....	309.06	.244	888	....	....	888	84.20
Lake Mahopac........		659.06	.875	575	....	....	575	2.36
Kirk Lake........		582.06	.158	565	....	....	565	2.84
Lake Gilead........		496.06	.190	380	....	....	380	.62
Lake Gleneida........		504.06	.284	165	....	....	165	.68
Barrett Pond........		778.06	.108	170	....	....	170	.57
White Pond........		829.56	.176	200	....	....	200	.97
Total (including small ponds)			19.32	99,280			104,443	360.44

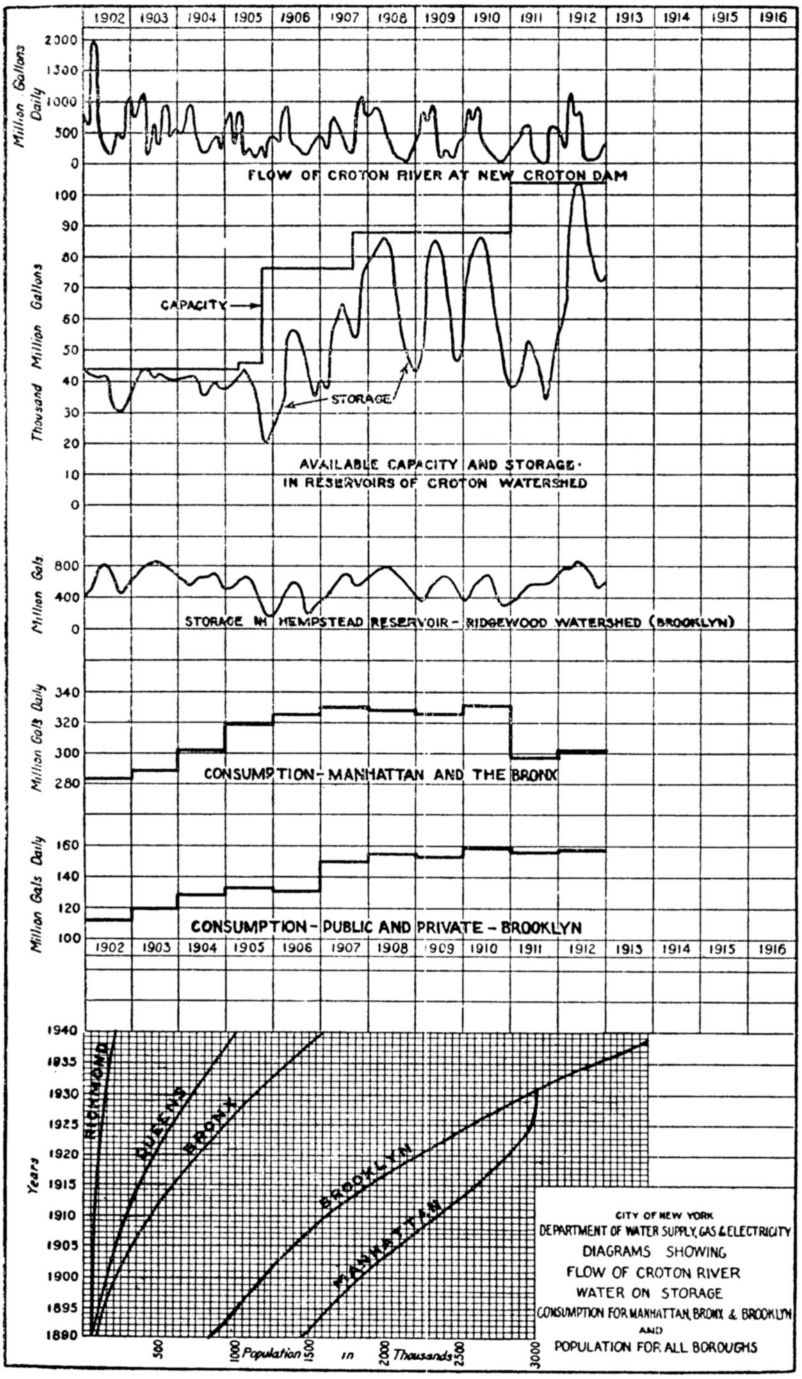


Plate III

PLATE III. WATER STORAGE AND CONSUMPTION

some 158 acres at the east side of this basin, originally proposed to form a second basin, is at present lying unused, with the excavation largely completed.

QUALITY OF CROTON WATER

The Croton water on average is of fair quality. The turbidity is usually moderate, averaging from 3 to 5 in the city; at times of heavy rains in the watershed, particularly when the level of the reservoirs is low, the turbidity may reach as high as 100.

The color is frequently high, running from 10 to 65 on the platinum scale. The watershed contains much swampy land, and the color is of vegetable origin. Odor is perceptible, and is sometimes very marked. Microscopic growths give the water a distinct taste, sometimes very disagreeable. Bacteria are moderate in number, particularly in the city, after the water is treated with hypochlorite of lime. 1912 records show a range of bacteria at 37° C. of from 5 to 1200 per cubic centimeter. B. coli, in 1912, are found in 1cc in 20 per cent of the tests.

The average alkalinity is 32.

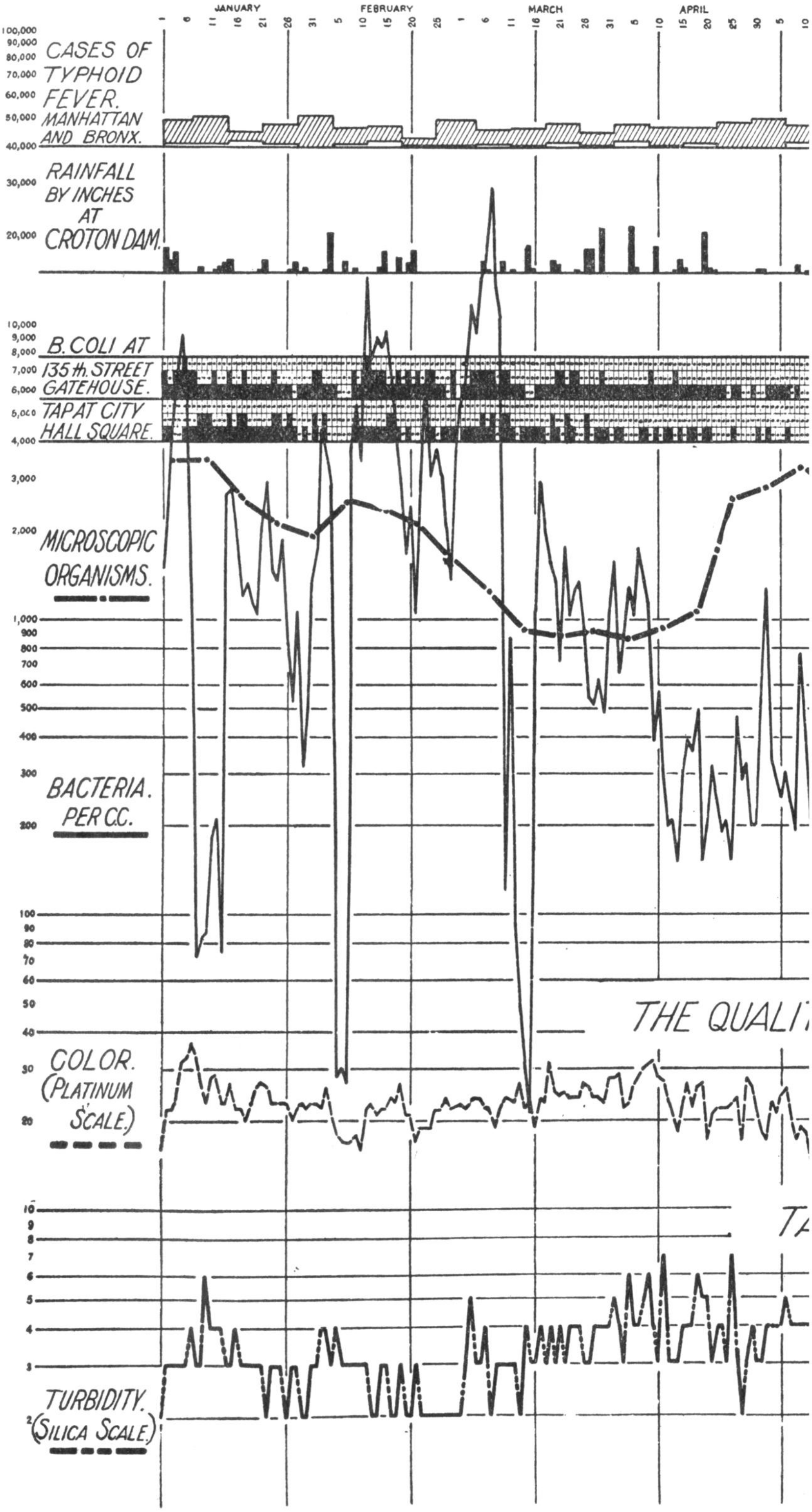
Plates IV and V show graphically the quality of the water for the years 1911 and 1912.

Table 2 gives the average of the analyses for the year 1912. Further data, showing in detail the color and microscopic organisms for the years 1907–1912 and the turbidity for the first part of the year 1912, are given in Tables 3, 4 and 5.

On Plates VI, VII and VIII are shown graphically some data of the characteristics of the Croton water. These curves have been very kindly furnished by Dr. Frank Hale, Director of the Mount Prospect Laboratories.

Plate VI shows the conditions on August 22, 1912. The thermocline is indicated at a depth of 13 feet. Above that line the temperature is high, 23° C., the dissolved oxygen high, 10 parts per million, the carbonic acid low, 1 part per million, and the microscopic organisms high, 6000 per cubic centimeter.

At a deeper level, where the water is quiescent and unaffected by surface influences, the temperature is somewhat lower, 6° C., the dissolved carbonic acid resulting from decomposing vegetation is high, 12.5 parts per million, the dissolved oxygen is very low, 1 part per million, but is always appreciable. The content of microscopic organisms is markedly lower, 800 per cubic centimeter.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CASES OF TYPHOID FEVER. MANHATTAN AND BRONX.
RAINFALL BY INCHES AT CROTON DAM.
B. COLI AT 135 th. STREET GATEHOUSE.
TAP AT CITY HALL SQUARE.
MICROSCOPIC ORGANISMS.
BACTERIA. PER C.C.
THE QUALIT
COLOR. (PLATINUM SCALE.)
TA
TURBIDITY. (SILICA SCALE.)

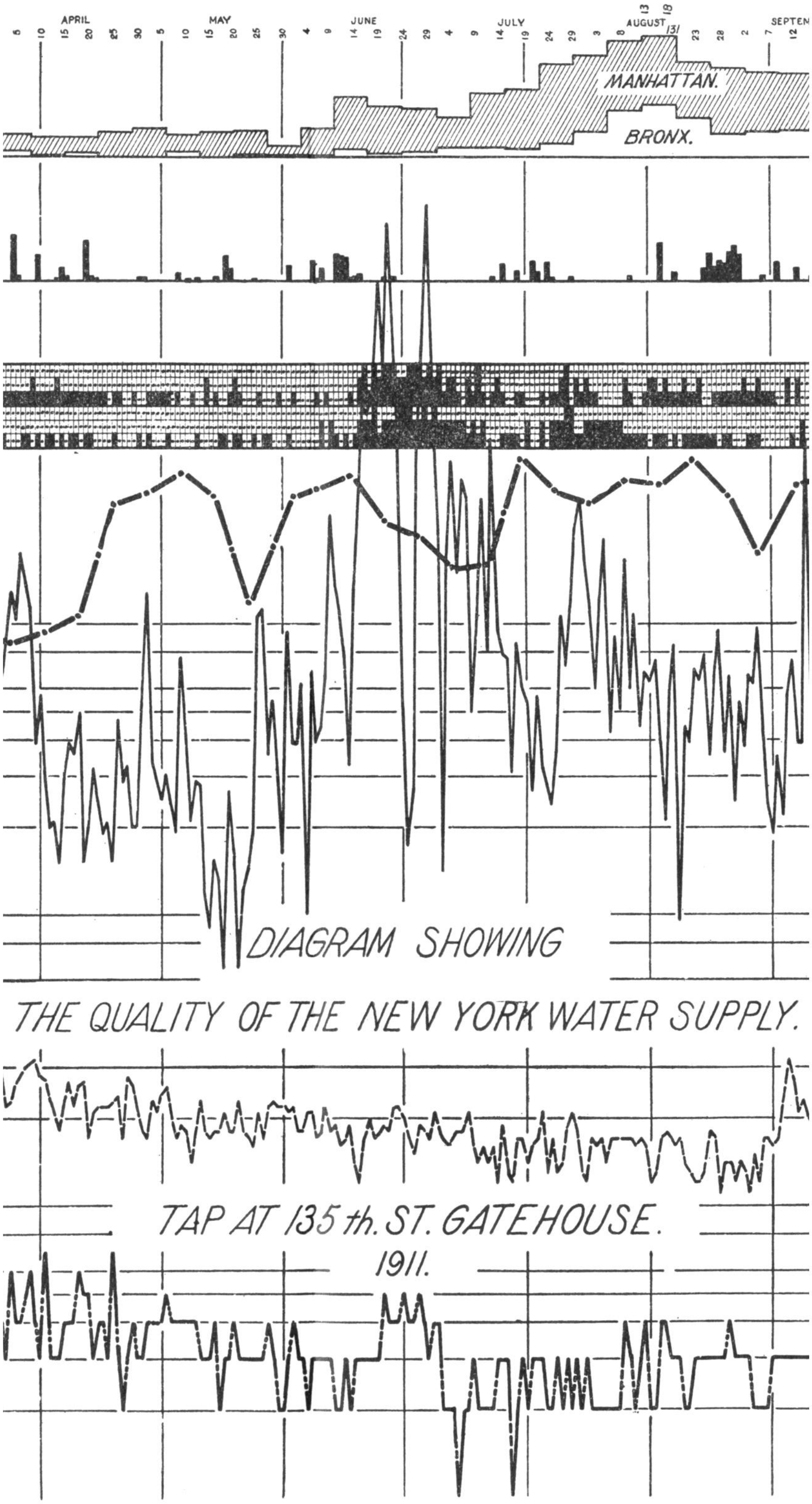

PLATE IV. QUALITY OF CROTON WATER, 1911

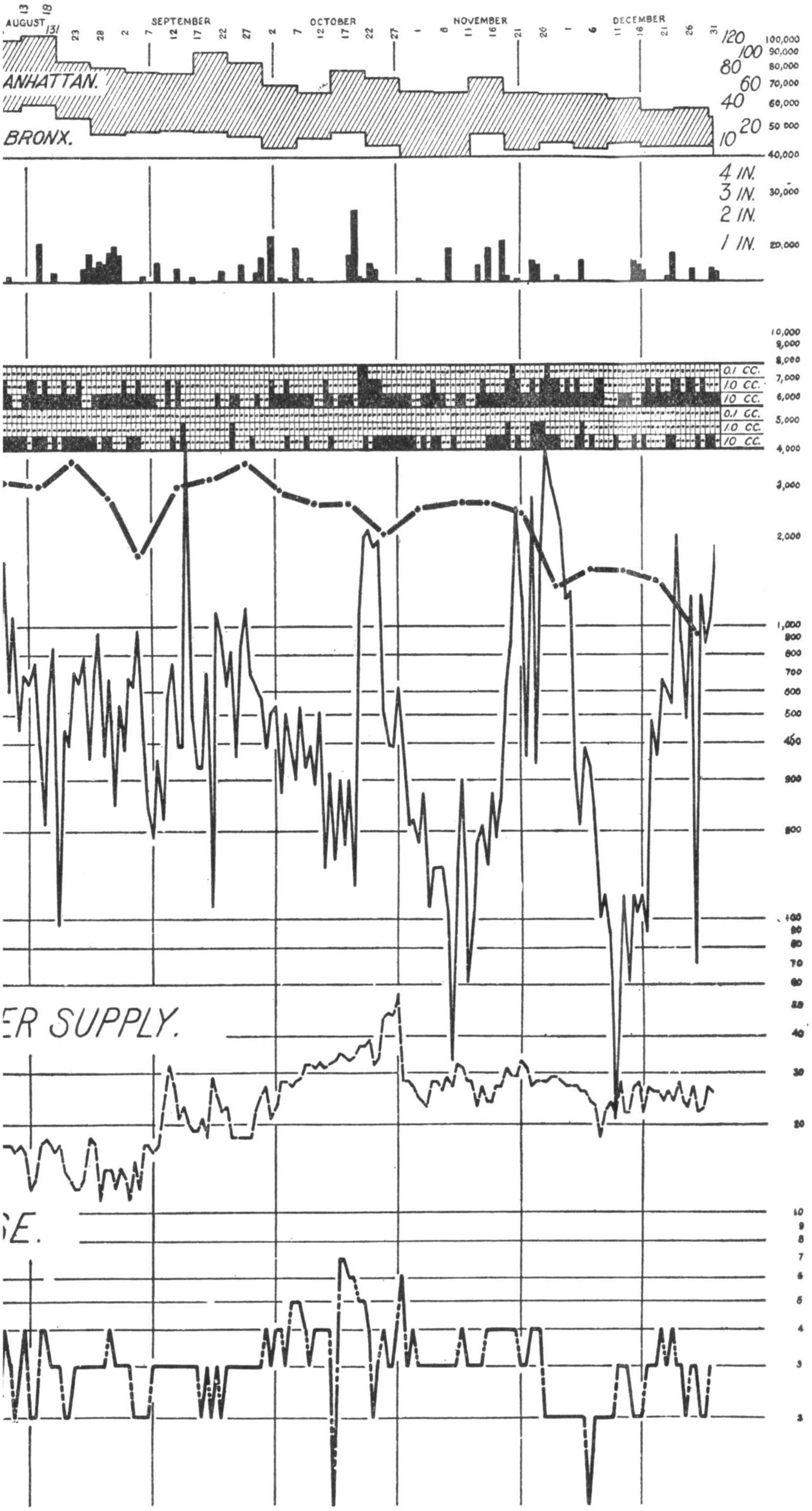
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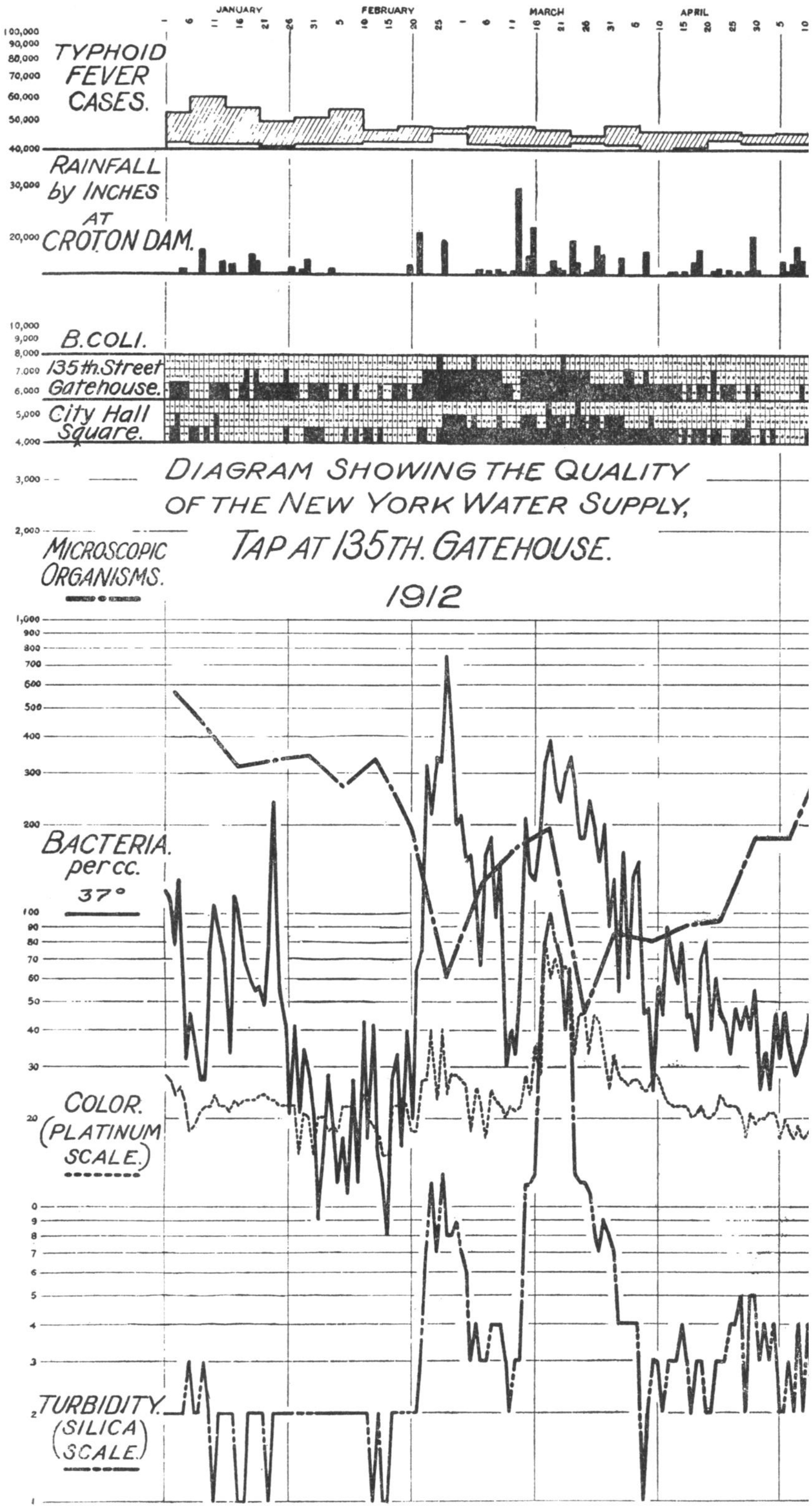
Plate IV

11



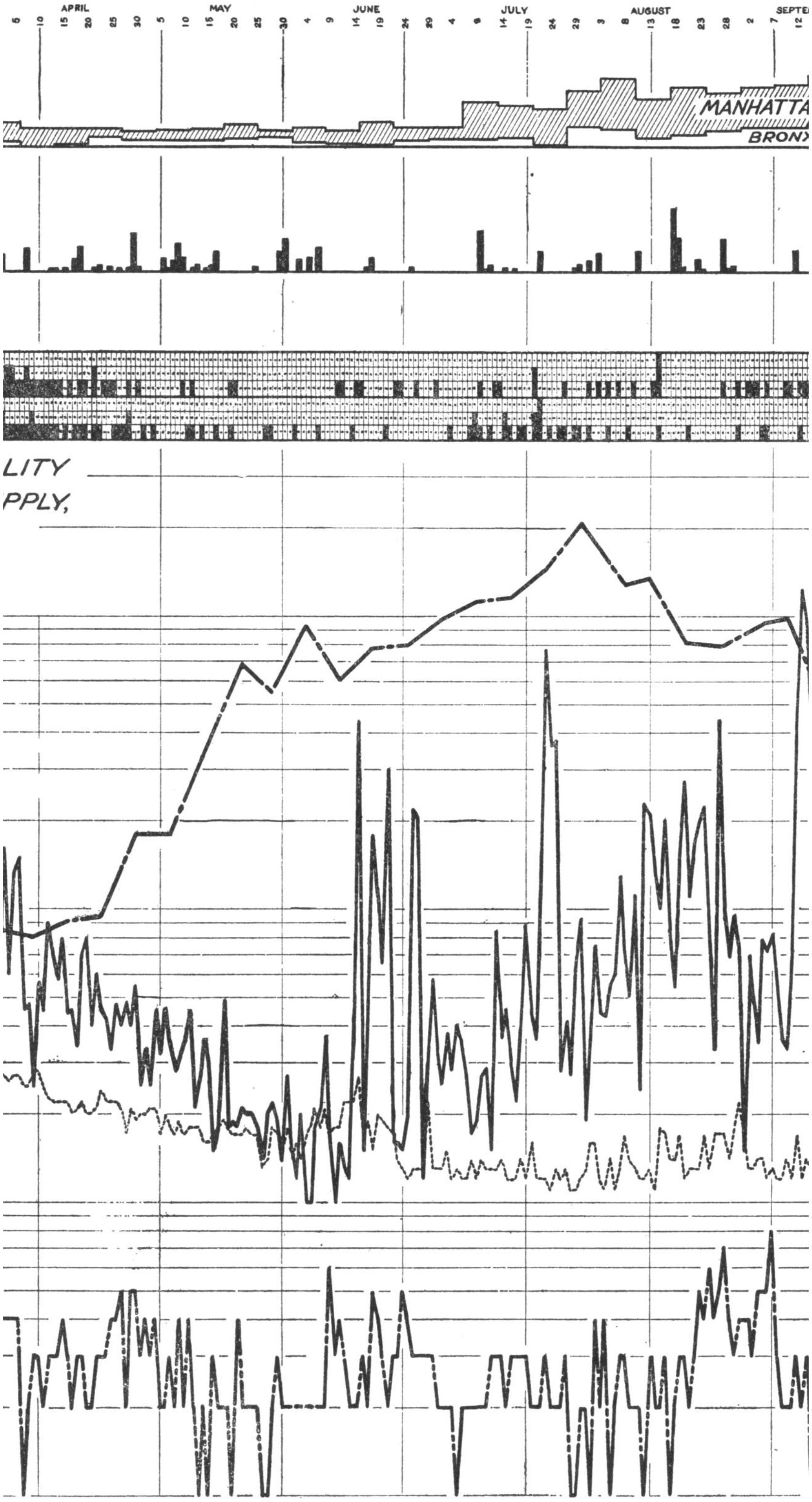
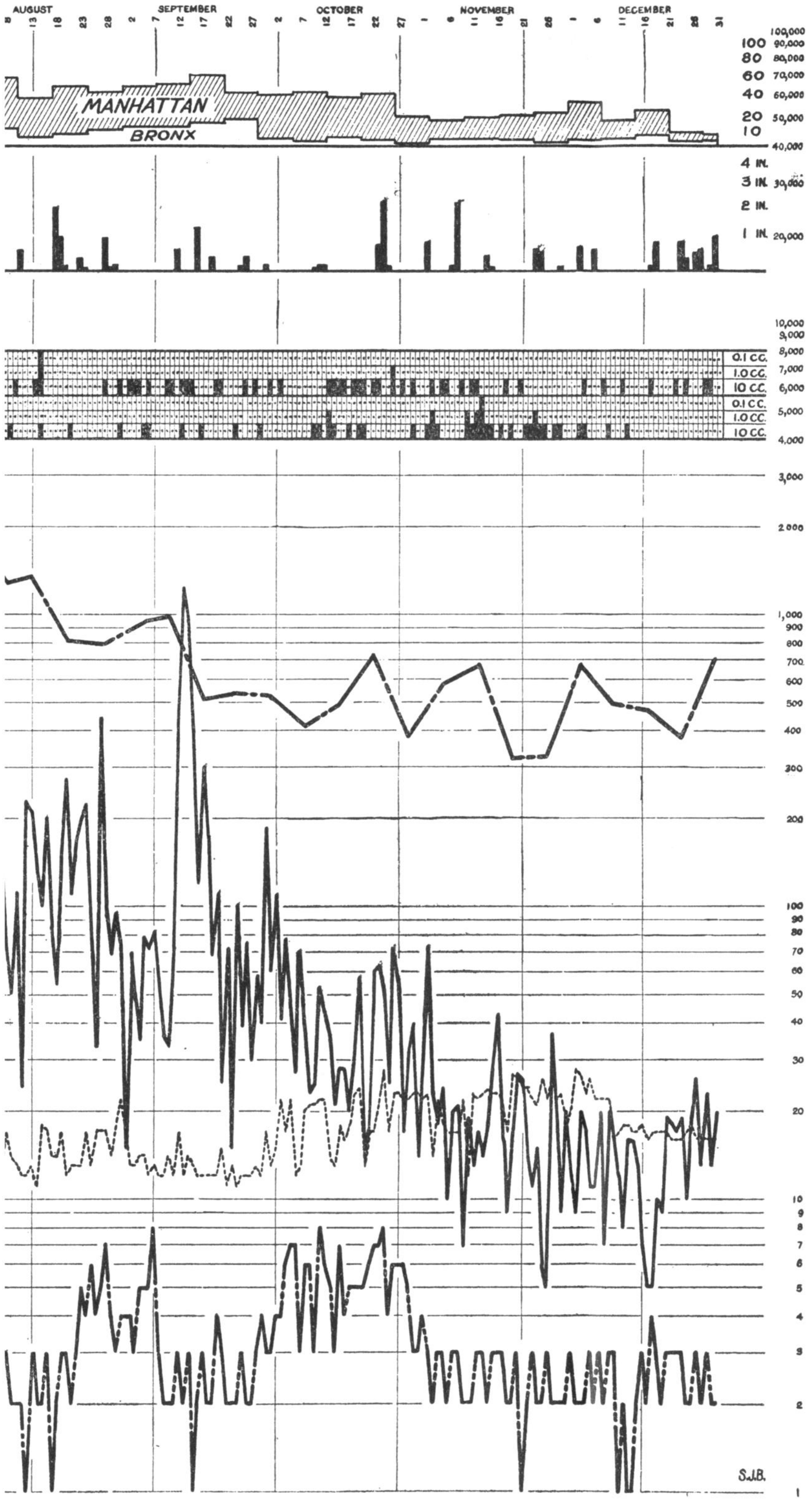


PLATE V. QUALITY OF CROTON WATER, 1912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SEPTEMBER
OCTOBER
NOVEMBER
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S.J.B.

Plate V

The indications from this diagram are that the quality of the water at low levels, as to odor and taste, which result largely from the microscopic organisms, will be materially better. The water is now being drawn in summer time from these low levels with decided improvement in the quality.

Plate VII shows the conditions on October 3, 1912. The fall overturn is under way, and the water is becoming of uniform quality. Further data, showing in detail the color and microscopic organisms for the years 1907–1912 and the turbidity for the first part of the

TABLE 2

Average quality Croton water 1912

KIND OF EXAMINATION	CROTON DAM SURFACE	JEROME PARK	135TH STREET GATE HOUSE	CENTRAL PARK	CITY HALL TAP
Physical:					
Turbidity	10	5	4	4	3
Color	31	19	20	18	18
Odor	12	22	22	22	22
Chemical:					
Albuminoid ammonia:					
In solution	0.153	0.124	0.131	0.152	....
In suspension	0.062	0.037	0.027	0.021	....
Total	0.215	0.161	0.158	0.173	.130
Free ammonia	.050	0.080	.059	.046	.028
Nitrites	.003	.003	.005	.005	.003
Nitrates	.08	.19	.209	.19	.21
Total solids	74	75	75	77	....
Loss on ignition	24	28	25	28	....
Fixed solids	50	47	50	49	....
Chlorine	2.5	3.2	3.1	3.2	....
Hardness	40	39	38	38	....
Alkalinity	32	32	32	32	....
Iron	.15	.33	.51	.29	....
Microscopical:					
Organisms	1,480	848	564	960	496
Amorphous matter	1,710	758	758	592	732
Bacteriological:					
Bacteria per cc. at 37 C.	315	64	79	62	48
Per cent. positive tests for B. coli:					
In 0.10 cc.	19	3	1	2	1
In 1. cc.	35	11	10	20	10
In 10. cc.	69	36	44	....	41

TABLE 3

Color (parts per million of platinum) Croton water, Jerome Park Reservoir Gate House No. 5

	1907	1908	1909	1910	1911	1912
January	16	27	12	17	22	26
	12	25	13	21	14	23
	30	26	14	16	16	21
	18	23	14	14	22	22
	21	....	....	6	17	15
February	17	23	18	19	16	18
	22	29	17	19	16	20
	21	26	13	18	13	18
	....	23	17	13	16	22
March	21	23	15	16	18	25
	20	22	13	21	13	22
	19	24	14	20	16	65
	14	24	12	17	14	48
	16	29	11	....	....	....
April	14	16	12	23	13	28
	15	16	11	21	14	22
	13	17	8	19	14	20
	13	15	11	18	18	22
	13	....	....	....	....	18
May	12	15	11	17	10	15
	12	15	12	18	10	....
	....	12	12	14	11	....
	....	12	14	14	11	10
	....	....	....	11	10	....
June	14	12	11	13	11	....
	12	10	12	14	16	....
	15	12	13	12	16	....
	11	8	11	12	15	....
	....	10	11	....	....	....
July	18	5	12	11	11	....
	11	10	11	8	18	....
	12	11	15	11	14	....
	11	10	11	11	13	....
	18	....	....	....	14	....
August	12	10	11	11	11	....
	13	10	9	11	16	....
	13	11	13	12	14	....
	18	12	12	13	14	....
	....	12	12	11	....	....
September	15	12	16	12	16	....
	12	17	17	14	22	....
	12	16	19	14	22	....
	13	16	16	14	18	....
	13	....	....	....	....	....

TABLE 3—Continued

	1907	1908	1909	1910	1911	1912
October	22	13	13	23	18	...
	18	13	17	17	23	...
	14	13	17	12	21	...
	21	11	12	17	26	...
	...	...	...	13	29	...
November	21	11	13	11	28	...
	18	13	13	11	23	...
	20	12	13	11	23	...
	22	12	11	11	29	...
	...	13	12	...	...	...
December	22	11	12	13	29	...
	25	13	15	16	26	...
	26	13	11	11	28	...
	26	14	17	12	24	...
	26	...	...	...	...	...
Average	17	16	13	14	18	...

year 1912, are given in Tables 3, 4 and 5. The thermocline is indicated at 30 feet near the bottom.

Plate VIII shows the conditions on October 17, 1912. The overturn is fully accomplished, and the water has practically uniform characteristics from top to bottom.

POLLUTION OF WATER

The pollution of the water is of various kinds.

1. The watershed is inhabited by about 25,000 people, whose sewage eventually reaches the reservoirs. Some part of these are provided with sewerage systems; a very small part of the population is provided with sewage disposal works.

To protect the water supply as far as is practicable, the city maintains four hypochlorite application plants in the watershed, located at Mount Kisco, Brewster, Lake Gleneida, and Katonah Brook. In addition, all the water passing through the new Croton aqueduct is treated with hypochlorite at Dunwoodie in South Yonkers.

The city also maintains a force of 89 men whose duty it is to patrol the entire watershed systematically, report on and see to the abatement of all nuisances or sources of infection they may discover, and operate the treatment plants. Of the above force, 28 men are regularly detailed and 61 are used for this service, as occasion demands.

TABLE 4

Total microscopic organisms, Croton water, Jerome Park Reservoir, Gate House No. 5

	1907	1908	1909	1910	1911	1912
January..........	2125	330	3020	2910	4845	540
	2415	490	2065	3105	6590	485
	845	500	2290	1785	5015	335
	1860	600	2990	1585	4650	360
	490	....	....	865	2525	345
February..........	280	455	2550	1135	3000	240
	550	200	5815	965	3540	330
	660	160	5115	715	4575	290
	....	245	4730	535	4055	100
March..........	625	540	4475	1075	4225	155
	765	375	3895	1910	4550	200
	250	445	4705	1785	4430	310
	980	220	3510	3105	4275	55
	345	230	3990	....	....	....
April..........	295	395	4460	2925	4885	85
	1030	660	2070	2550	3545	125
	800	345	1835	2485	3735	140
	1420	365	1510	4530	3805	135
	2265	....	....	....	....	240
May..........	2465	695	1030	2805	1070	245
	2170	1185	1195	3375	1820	....
	....	655	340	3410	1745	....
	....	530	280	3300	1110	....
	....	....	....	3080	2310	....
June..........	1910	350	550	3565	1345	....
	3315	500	565	3320	1720	....
	2385	520	170	2425	1435	....
	1500	455	550	1895	2465	....
	....	200	40	....	....	....
July..........	1580	380	205	2520	4980	....
	1050	325	155	1075	2470	....
	655	245	810	800	....	....
	235	215	2530	260	4475	....
	430	....	....	....	6090	....
August..........	260	195	1695	1100	6280	....
	940	535	1965	1665	5580	....
	475	435	865	1735	4960	....
	650	1140	1950	3650	3755	....
	....	790	2135	3825	....	....
September..........	1130	1145	3360	5325	3516	....
	1530	835	3525	7100	3725	....
	990	1270	2530	9300	4215	....
	1360	1650	3750	6050	4630	....
	480	....	....	....	....	....

TABLE 4—Continued

	1907	1908	1909	1910	1911	1912
October	2645	16110	4725	7480	3450	....
	2220	1050	3290	12225	3525	....
	1150	1300	2960	12680	3630	....
	2855	1685	4940	9660	2695	....
	....	....	....	12060	2825	....
November	6460	1470	3655	13100	2725	....
	2985	1295	3425	9828	2640	....
	2615	450	3155	7800	2985	....
	1500	1465	4540	7138	2895	....
	....	1705	5315	....	....	....
December	1385	1660	4275	5160	2190	....
	2275	1925	5535	5060	1810	....
	995	780	4515	6548	1820	....
	820	1805	....	5360	1365	....
	175	....	....	....	....	....
Average	1435	750	2756	4244	3444	....

2. Microscopic vegetable growths discoloring the water and giving it a disagreeable taste and odor result from the swampy lands forming part of the reservoir system.

To reduce these as far as possible, copper sulphate is applied by the reservoir forces.

3. The watershed contains some 13 miles of railroad track within 300 feet of the flow line, and 18 railroad bridges aggregating 1700 feet in length. The sewage from the passenger trains enters the reservoirs practically raw, and may often contain pathogenic bacteria. So far, it has not been practicable to enforce proper sanitary control over the wastes from these railroad trains.

The difficulties of asserting authority and abating nuisance are considerable under existing laws, and make watershed protection harder than it should be.

4. Highway bridges, 19 in number, aggregating 4200 feet in length, discharge their wash into the reservoirs.

5. Wash from roads and runoff from farm lands, and the existence of some 24 square miles of swampy land, cause at times a heavy turbidity, and at all times a marked color, bad odor and taste.

TABLE 5

Turbidity of Croton water at 135th Street Gate House 1912

	JANUARY	FEBRUARY	MARCH	APRIL
1	2	2	7	7
2	2	2	6	4
3	2	2	3	4
4	2	2	4	4
5	2	2	3	4
6	2	2	3	4
7	2	2	4	1
8	2	2	4	2
9	3	2	4	3
10	2	2	3	3
11	1	2	2	2
12	2	1	3	3
13	2	2	3	3
14	2	1	12	3
15	2	1	12	4
16	1	2	13	3
17	1	2	40	2
18	2	2	80	3
19	2	2	100	3
20	2	2	80	2
21	2	2	70	....
22	1	3	40	....
23	2	7	65	....
24	2	12	13	....
25	2	7	12	....
26	2	12	12	....
27	2	8	11	....
28	2	8	8	....
29	2	9	7	....
30	2	....	9	....
31	2	....	8	....

TYPHOID FEVER IN NEW YORK

Typhoid fever has been moderate in New York particularly of late years. Table 6 gives death rates for New York City and other large American cities for the last thirty years.

POTENTIAL DANGER

The possible danger to the health of the community from infection from the polluted drinking water cannot be evaluated into definite figures. Typhoid statistics are a general indication of the

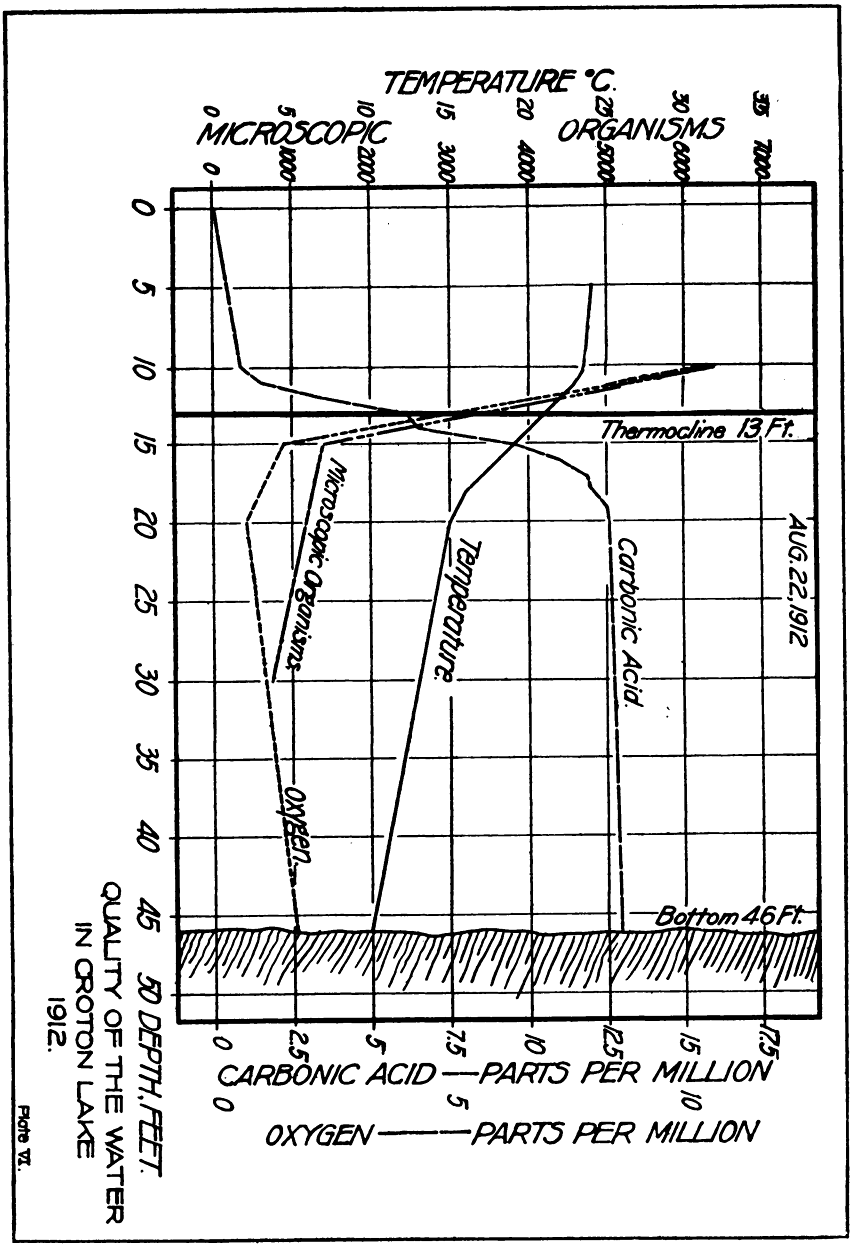


PLATE VI. QUALITY OF CROTON WATER

TABLE 6

Annual typhoid fever death rates for various American cities. In deaths per 100,000 population

YEAR	CHICAGO	MILWAUKEE	DETROIT	CLEVELAND	BUFFALO	TORONTO	BOSTON	NEW YORK	MANHATTAN AND THE BRONX	PHILADELPHIA	BALTIMORE	WASHINGTON	CINCINNATI	PITTSBURGH	SAN FRANCISCO	ST. LOUIS	NEW ORLEANS
1880	34	37	......	44	......	44	42	25	......	58	59	54	70	135	34	40	24
1881	105	47	......	99	67	66	56	38	......	74	58	86	71	151	37	53	30
1882	82	32	......	68	69	71	57	32	......	73	47	66	55	158	61	45	33
1883	62	25	......	65	34	81	52	32	......	64	35	62	51	107	64	41	23
1884	56	31	......	60	42	63	56	29	......	71	42	76	56	70	58	42	25
1885	75	28	......	34	23	59	40	27	......	64	42	65	42	76	44	31	17
1886	69	30	39	56	28	46	34	26	......	64	39	71	54	68	49	30	13
1887	50	31	65	52	34	61	44	26	......	63	41	78	142	128	23	28	15
1888	47	42	46	47	29	52	40	23	......	77	42	87	70	87	33	31	19
1889	48	28	31	74	30	46	43	24	......	71	47	94	49	95	55	33	17
1890	92	41	19	69	40	93	35	22	......	64	59	112	69	132	44	31	21
1891	174	33	34	50	51	100	34	23	......	64	35	82	62	101	42	29	24
1892	124	30	94	59	34	47	29	22	......	40	44	89	40	100	32	93	20
1893	54	35	42	52	37	45	31	21	......	41	49	86	44	111	32	44	15
1894	38	25	28	29	59	26	29	17	......	33	47	91	55	56	37	34	29
1895	38	26	24	35	26	27	33	17	......	40	36	86	39	78	34	21	44
1896	53	18	23	43	20	27	31	16	......	34	38	58	52	62	26	20	33
1897	29	12	15	23	20	18	33	16	......	33	37	48	32	64	19	23	52
1898	41	17	22	34	27	16	34	21	......	52	36	71	33	73	41	17	66
1899	27	17	13	32	24	20	30	16	......	75	29	73	37	111	22	23	55

1900	20	17	27	54	26	20	26	21	......	35	35	78	39	144	13	29	40
1901	29	22	21	36	27	17	25	20	......	34	27	60	55	125	22	34	48
1902	45	15	24	33	33	13	24	21	......	44	42	78	62	134	27	37	45
1903	32	17	20	114	35	16	20	17	......	69	36	48	42	134	......	47	39
1904	20	14	20	48	23	23	23	17	......	53	37	47	79	142	27	36	36
1905	17	23	21	15	23	16	20	16	......	48	36	48	40	99	24	20	32
1906	19	31	24	20	23	26	20	15	......	72	35	50	70	130	......	17	30
1907	18	26	35	19	28	22	10	17	......	59	41	35	45	125	......	15	55
1908	16	17	22	13	20	20	25	12	11	35	33	37	18	45	......	14	33
1909	13	23	23	13	23	23	14	12	12	21	25	33	13	23	......	16	29
1910	14	45	20	19	20	41	12	12	11	17	42	23	6	28	......	13	32
1911	11	19	17	15	25	20	9	11	10	14	27	21	11	26	......	11	31
1912	8	25	18	6	11	12	8	10	7	13	24	22	7	13	14	14	14

NOTE: New York includes Borough of Manhattan only through 1898—since 1898 Greater New York.

average sanitary quality. A high typhoid death rate shows generally a dangerous water; a low rate, such as ours in New York, shows a water of safe average quality. It does not, however, show that the water may not, at some future time, become grossly polluted by bacteria causing diseases such as typhoid or other intestinal diseases, in the watershed, and such infection may be transmitted to the city.

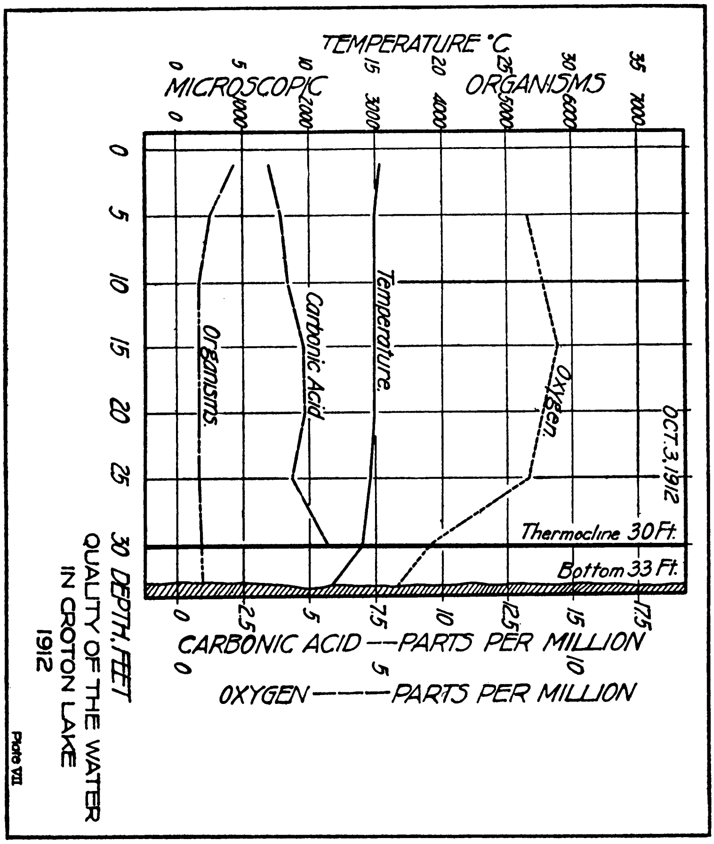


Plate VII. Quality of Croton Water

For some years the water reaching the city has been treated with hypochlorite, and the grosser sources of pollution in the watershed are individually treated. But, while such treatment we know to be fully effectual and reliable when treating a filtered water or a clear water of small organic content, it is only a rough palliation for waters such as the Croton.

PRELIMINARY STEPS TOWARD PURIFICATION

In 1899 the New York City Board of Health recommended the filtration of the Croton water.

Mr. John R. Freeman states in his report of March 23, 1900, on the Water Supply of New York:

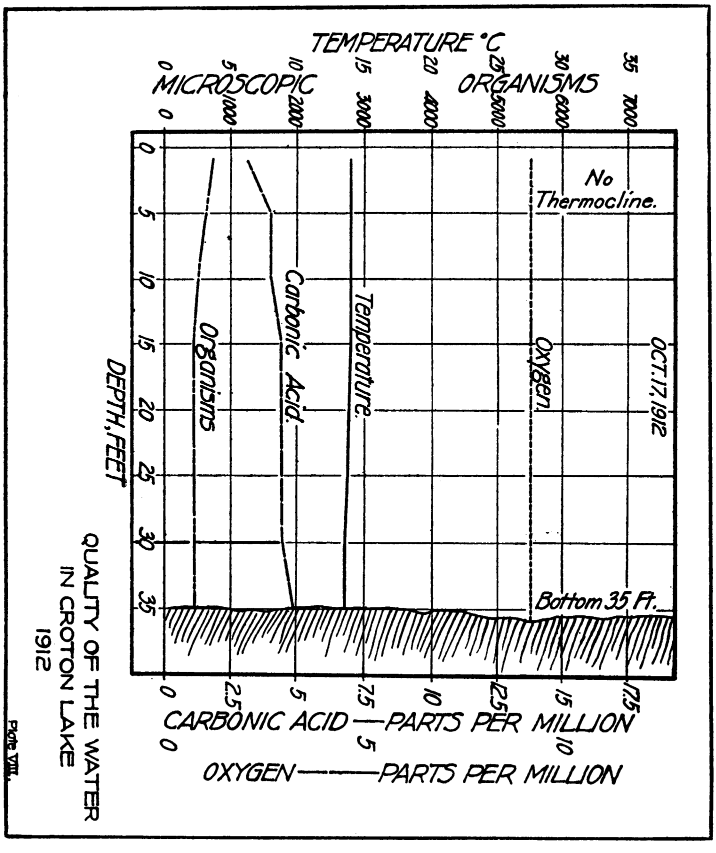


PLATE VIII. QUALITY OF CROTON WATER

> I venture to express the belief that by 20 years hence the public will have become educated to demand a higher standard of purity in public water supplies, and all future work should be laid out with a view to filtration 10 or 20 years hence of all water entering the distribution system.

In 1903, the Burr-Hering-Freeman Commission on the Additional Water Supply for the City of New York stated:

> Regarding the Croton water, the Commission urges that suitable lands be secured at once upon which to erect a filter plant sufficient in size to purify the entire supply obtained from this source.

On November 22, 1904, Mr. J. Waldo Smith, then Chief Engineer of the Aqueduct Commission, recommended to the Commission the use of the easterly half of the Jerome Park site for a covered reservoir for the filtered Croton water, and the employment of Messrs. Hazen and Whipple to report on this project. Hazen and Whipple reported favorably on filtration on December 12, 1904.

On July 25, 1905, Dr. Thomas Darlington, Commissioner of Health, reported:

> A careful study of the conditions on the Croton watershed and of the various other supplies of the Greater City, covering a period of many months, has convinced me of the necessity for the establishment of filtration plants.

On January 16, 1905, the Burr-Hering-Freeman Commission, reported on the recommendation of Mr. J. Waldo Smith, recommending the suspension of work on the east basin of the Jerome Park reservoir, in order to permit of the use of this site for a covered reservoir. This recommendation was adopted by the Aqueduct Commission on December 21, 1905.

On March 28, 1906, Mr. I. M. de Varona, Chief Engineer, Department of Water Supply, Gas and Electricity, submitted a report to the Commissioner of the Department on sites for a filter plant and recommended that the Jerome Park site be used for the filters themselves, as well as for the reservoir. On May 23, 1906, the Board of Estimate granted an appropriation for the purpose of investigating the Croton water supply and preparing plans for filter construction.

Messrs. Hering and Fuller were appointed as consulting engineers for this investigation. The results of this investigation were embodied in a report dated October 30, 1907, by Mr. I. M. de Varona, approved by Messrs. Hering and Fuller.

The recommendation was made to build 42 acres of slow sand filters, superposed on a filtered-water reservoir; these filters would be operated at a normal rate of 10,000,000 gallons per acre per day. The filters would be cleaned by the Blaisdell washing machine. Coagulation was to be employed during eight months of the year; a settling basin of eighteen hours' capacity was to be provided, and a clear-water reservoir of 575,000,000 gallons capacity. To bring the water to the filters, the water level at the reservoir would be raised 1½ ft.; the new Croton aqueduct would supply 310,000,000 gallons per day, and the old Croton aqueduct 90,000,000 gallons per day, as a maximum.

This project was pigeonholed, very likely because the panic of that year and the difficulty of selling bonds made public improvements of this character impracticable.

On May 18, 1911, on the recommendation of the Commissioner of Water Supply, Gas and Electricity, an appropriation of $8,690,000 was made by the Board of Estimate and Apportionment for the construction of the Jerome Park filters. The ordinance for the issue of corporate stock was adopted by the Board of Aldermen June 20, 1911, and took effect July 3, 1911.

DESIGN OF FILTER PLANT

Plans for the construction were made under the direction of Mr. I. M. de Varona, Chief Engineer of the Department, the writer as Consulting Engineer, and Mr. E. G. Manahan, Division Engineer, in immediate charge.

COMPARISON OF TYPES OF FILTERS

The first step was a thorough investigation of the relative merits of slow sand filters both with and without coagulant and of mechanical filters. A set of general plans was drawn for each type of construction and comparative estimates made of the costs of construction and operation.

The results of this investigation are embodied in a report by Mr. I. M. de Varona dated May 20, 1912. Tables 7, 8 and 9 given herewith show the costs of construction, operation, and fixed charges, for slow sand filters, modified sand filters and mechanical filters.

The above tables are based upon an average quantity filtered of 320,000,000 gallons daily.

Fixed charges include interest on investment at 4 per cent plus ¾ of 1 per cent for extraordinary depreciation as distinguished from repairs and renewals of parts.

The recommendations resulting from this investigation are stated in a report by the writer dated May 21, 1912, as follows:

TABLE 7

Jerome Park filters. Comparative estimates of sand and mechanical filters

	SAND FILTER PLANT						MECHANICAL FILTER PLANT		
	Without Coagulation. Rate 5,000,000 gallons daily			With Coagulation. Rate 8,000,000 gallons daily			Rate 125,000,000 gallons daily		
	Area	Capacity	Cost	Area	Capacity	Cost	Area	Capacity	Cost
	acres	*million gals.*		*acres*	*million gals.*		*acres*	*million gals.*	
Settling reservoirs, including mixing chamber, head house, laboratory, drainage and inlet conduit for filters			$262,000	34	280	$2,401,600	12	88	$1,690,000
Filters and equipment, including filter-water reservoir beneath	76		7,880,000	48		4,971,100	4.6		2,080,000
Filtered-water reservoir (part not beneath filters)	43		1,565,400	43		1,565,400	55		2,216,000
Filtered-water reservoir:									
Total capacity		640			490			365	
Capacity above El. 123		56			42			54	
Gate house changes and additions			233,000			233,000			283,000
Changes in aqueducts and west basin			60,000			60,000			60,000
Plant for power and heat			120,000			120,000			110,000
Engineering and contingencies			2,024,100			1,870,200			1,288,000
Total			$12,144,500			$11,221,300			$7,727,000
Less cost of supervision (to come from Budget, and estimated at 5 per cent)			506,000			467,600			322,000
Total from Appropriation			$11,638,500			$10,753,700			$7,405,000

TABLE 8

Jerome Park filters. Comparative charges for a sand filter plant and a mechanical filter plant per million gallons filtered (based on an average of 320,000,000 gallons filtered daily)

	SAND FILTERS		MECHANICAL FILTERS
	Without coagulation	With coagulation	
Administration and laboratory......	0.23	0.23	0.23
General work and caring for grounds	0.11	0.12	0.13
Operating and cleaning filters........	0.25	0.25	0.11
Chemicals and their application......	0.08	1.33	1.73
Light, heat and power...............	0.64	0.64	0.66
Repairs, renewals and supplies......	0.28	0.30	0.25
Cleaning, settling basins and disposal of sludge.......................	0.00	0.10	0.10
Cost of Operation............	$1.59	$2.97	$3.21
Interest on cost of construction; and extraordinary depreciation as distinguished from repairs and renewals of parts; 4¾ per cent of cost............................	4.94	4.56	3.14
	$6.53	$7.53	$6.35

TABLE 9

Jerome Park filters. Comparison of sand and mechanical filters. Showing investment cost, cost per million gallons filtered, and annual cost

	TOTAL INVESTMENT	FIXED CHARGES PER MILLION GALLONS	COST OF OPERATION PER MILLION GALLONS FILTERED	TOTAL COST PER MILLION GALLONS FILTERED	TOTAL ANNUAL COST
Sand filter plant without coagulation rate 5 m.g.d.....	$12,144,500	$4.94	$1.59	$6.53	$763 000
Sand filter plant, with coagulation; rate 8 m.g.d..........	11,221,300	4.56	2.97	7.53	880,000
Mechanical filter plant	7,727,000	3.14	3.21	6.35	742,000

CONCLUSIONS AND RECOMMENDATIONS

Plain sand filtration will not remove uniformly the turbidity and color in the Croton water sufficiently to obtain a clear, colorless water at all times. In fact, there would be a noticeable vegetable stain in the filtered water obtained with this type of filter for some six or eight months during the average year. Following very heavy rains the effluent of plain sand filters would also show somewhat excessive turbidities due to silt and clay. Such conditions prevailed during the latter part of the past winter.

With well managed plants of either of the three types satisfactory results would be uniformly obtained as to freedom from objectionable bacteria and obnoxious odors.

While a plant of the plain sand filter type would not uniformly produce a water of satisfactory appearance as to color and turbidity, it is perfectly feasible to obtain at all times a fully satisfactory grade of filtered water by either the modified sand filter method or by mechanical filters. So far as quality of filtered water is concerned, there is no choice between these methods. Each would be fully satisfactory as to efficiency.

The problem, then, becomes one of considering whether mechanical filters or modified sand filters would produce the desired result at least cost, when consideration is given both to the first investment and to the cost of operation and maintenance. On the latter score the estimates which have been prepared leave no room whatever for doubt. Mechanical filters, when compared with modified sand filters, show a saving of first cost of practically $3,500,000 and an annual saving of $138,000 when fixed charges are added to operation and maintenance of each type of filter.

I am firmly convinced, therefore, of the soundness of the conclusion that it is best to build mechanical filters for the purification of the Croton water supply and herewith I formally and unqualifiedly recommend the adoption of filters of the mechanical type.

The plans and estimates so made, with the data on which they were based, were then submitted to a consulting board of water purification experts, appointed by the Commissioner of the Department; this board consisted of Messrs. Allen Hazen, George A. Johnson, Frank A. Barbour, W. P. Mason and James H. Fuertes.

The points submitted to this board of experts for investigation were the following:

Mechanical filters

1. Are the mechanical filters, as shown by the plans of the Department, in accordance with modern practice?
2. Will these mechanical filters properly purify the water and render it clear and colorless?

3. Are the estimates of cost of constructing these mechanical filters reasonable?

4. Is the estimated cost of operation of these mechanical filters reasonable?

Sand filtration

1. Will it be necessary to use coagulants in order to obtain clear and colorless filtered water at all seasons of the year?

2. Are the sand filters, as shown in the general plans of the Department, in accordance with modern practice where coagulants are to be used?

3. Will these modified sand filters properly purify the water and render it clear and colorless?

4. Are the estimates of cost of constructing these sand filters reasonable?

5. Is the estimated cost of operation of these sand filters reasonable?

The Board reported to the Chief Engineer on June 10, 1912, and the substance of the report may be summarized by quoting from the Chief Engineer's letter dated June 20, 1912, as follows:

> I enclose herewith copy of report made by the Consulting Board of Experts on the plans for the filtration of the Croton water supply, answering the questions propounded by us.
>
> They report that "the mechanical filters shown by the plans are in general accordance with modern practice."
>
> That they believe that they will properly purify the water and render it clear and colorless.
>
> That the estimates of cost and operation appear to them to be reasonable.
>
> That, in order to produce clear water, and water that is sufficiently colorless to be satisfactory at all times, with sand filters, it will be necessary to use coagulants for a portion of the time.
>
> That "it is open to doubt whether the Jerome Park site can be considered at the present time as one permitting of suitable plans for sand filters of such type" as they should be willing to call generally in accord with modern practice.
>
> These conclusions fully establish those of the preliminary report made by me to you, in which the construction of mechanical filters was advocated.
>
> The suggestions made by the Board as to aeration, use of sulphate of copper, etc., are in accordance with the views of this Bureau and will receive due and timely consideration.

The detail plans and specifications for the mechanical filter plant had in the meantime been in the course of preparation, and were completed June 25, 1912.

DETAIL PLANS FOR MECHANICAL FILTERS

Site. The general appearance of the site at Jerome Park looking from the west to the east is shown on Plate IX; a map of the site and the surrounding streets is shown on Plate X. A topographical plan of the site is shown on Plate XI.

Hydraulics. The existing west basin, which contains the Croton water, has a flow line at elevation 131.5, Public Works datum. (This datum is 2.67 feet above United States Coast and Goedetic Survey datum, and is 3.61 feet above Croton datum.) A moderate amount of change of the walls and banks of this basin would permit raising the flow line to elevation 133, and this elevation was adopted. A loss of 7 feet through the whole filter plant was allowed and the high elevation for the filtered-water reservoir fixed at 126; a minimum elevation in the filtered-water reservoir of 123 would permit of proper supply to the City at a maximum rate of 400,000,000 gallons per day, with the Central Park reservoir at elevation 111.

The supply through the new Croton aqueduct was taken as a maximum of 310,000,000 gallons per day. A careful study of all avaiable data on the resistance and delivery of this aqueduct, particularly of a series of gagings made by the Board of Water Supply, led to the conclusion that the delivery of the aqueduct when practically full could be represented by the formula

$$V = 134 \sqrt{r.s.}$$

where v is velocity in feet per second,

r the hydraulic mean radius,

s the slope.

The hydraulic gradient of the aqueduct under these conditions, assuming a coefficient in the Chezy formula of 130, is given in Table 10.

At such places where the internal pressure on the aqueduct makes it necessary the aqueduct was to be suitably reinforced by additional earth cover. Minor changes in blowoff houses were required to suit the raw-water elevations. The maximum discharge of the old Croton aqueduct was taken from Mr. John R. Freeman's Report (Fig. 43) as 90,000,000 gallons per day.

The average yield would require practically only the capacity of the new aqueduct. For greater demands, a pumping equipment lifting the water in the old aqueduct over a static head of about $5\frac{1}{2}$ feet was projected.

Of the 7 feet of effective head for the filter plant, 1 foot was required

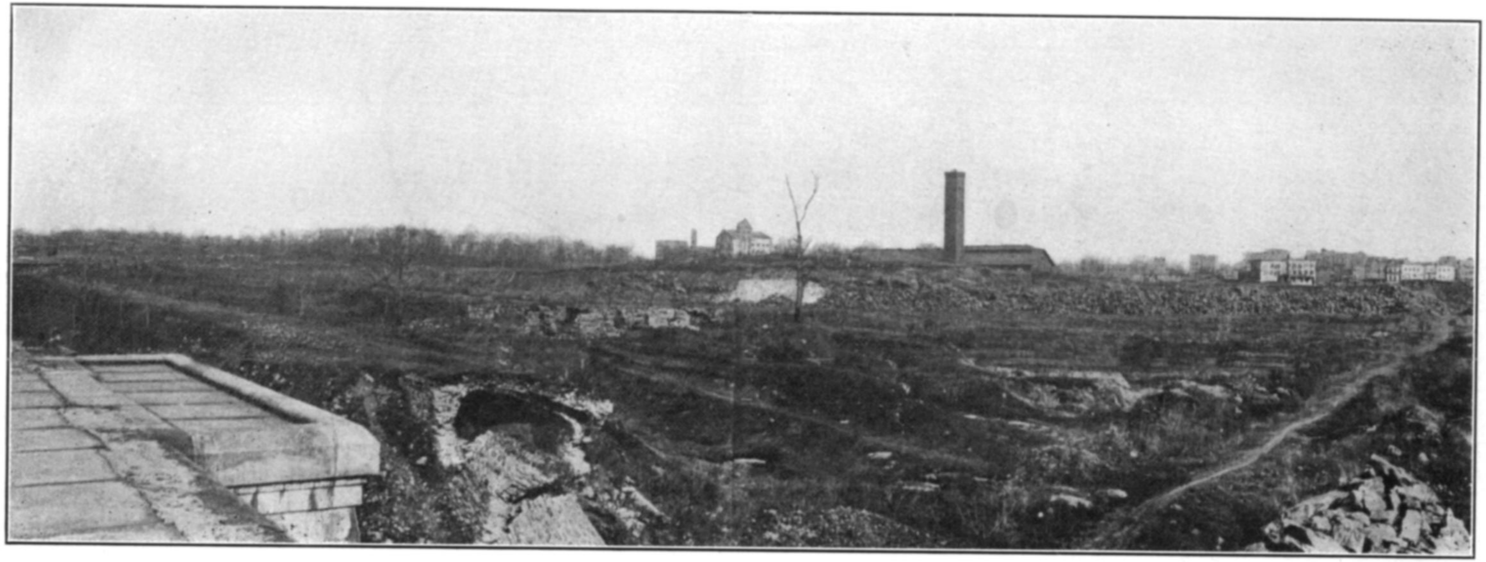


PLATE IX. SITE OF FILTER PLANT

for the mixing chamber, 3 inches for the Venturi meter, 9 inches for various gate chambers, channels, and for the coagulating basins; the remainder, 5 feet, was available for the filters proper.

AERATION

The needs and possibilities of aeration were studied without arriving at a conclusion. Plates VII and VIII showing deficiencies in dissolved oxygen, and large content of carbon dioxide, together with the growth of microscopic organisms, indicate but do not establish that eration might be helpful. Estimates were made for locating an aeration plant at Pocantico cut, about 10 miles below the new Croton dam, and the installation of the aerating plant would require a raising of the working water level above it of 15 to 20 feet. This would for a good part of the time have been feasible.

A series of practical tests of the water was required before definitely adopting aeration as a necessary part of the water treatment.

THE TURBIDITY AS AFFECTED BY THE CATSKILL SUPPLY

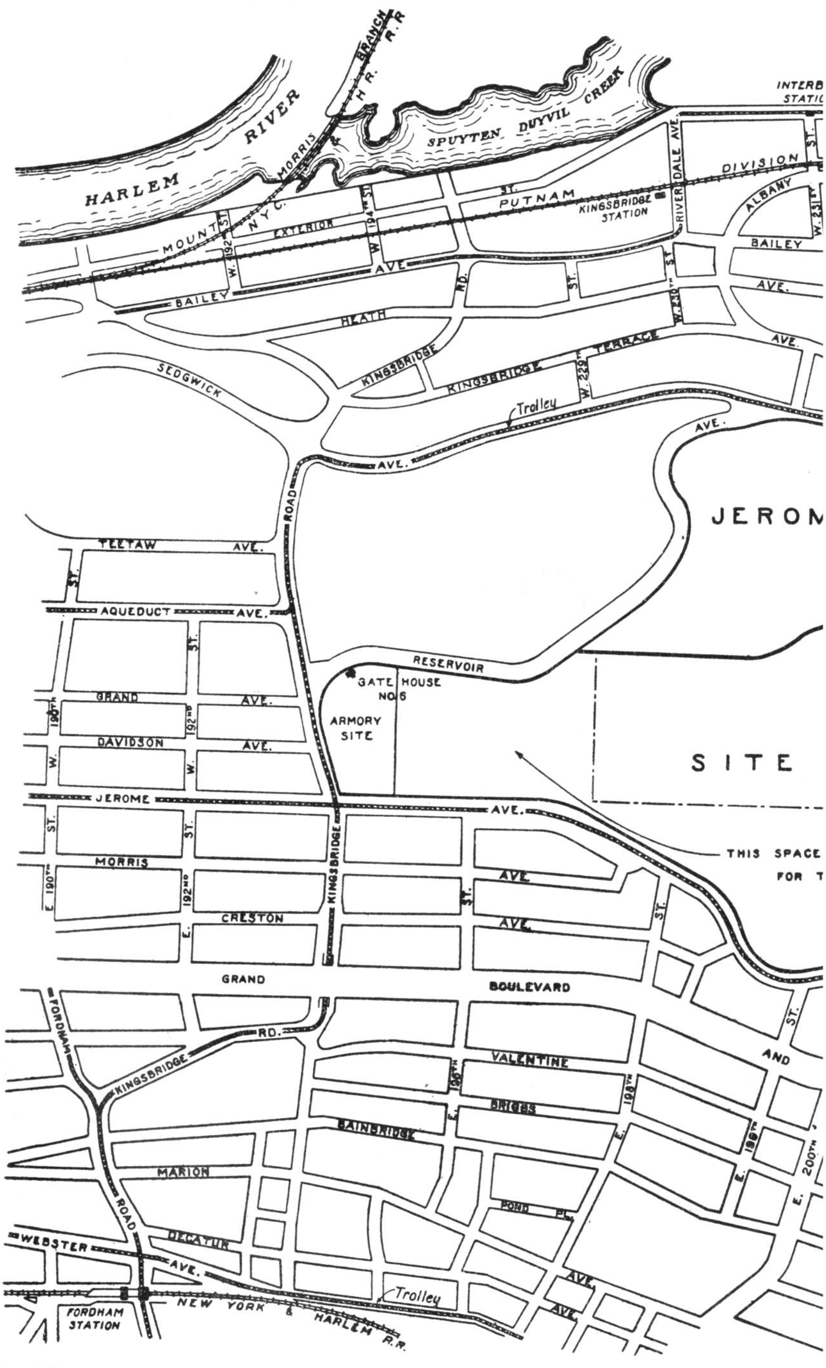
Some study was given to the possible effect of the use of the Catskill supply in times of high turbidity as a substitute for the Croton. The question considered was, if it would be practicable to cut off the Croton supply at such times, using only Catskill water, until the Croton water became less turbid.

The indications are that the Catskill water will at such times be likely to suffer from excess turbidity as well as the Croton water. From all information available it did not seem probable that the Catskill water would be any better at such periods, and it was decided that no reliance could be placed on such assistance, and that the Croton water must at all times be handled so as to give proper results independent of the Catskill water.

CHEMICAL APPLICATION

The chemicals used, and the average and maximum amounts were as follows:

For coagulation, aluminum sulphate, average 1 grain per gallon, maximum 2 grains per gallon. Lime or soda were to be used when necessary to neutralize excess carbonic acid in the filtered water; the quantities contemplated were: lime, maximum, 2 grains per gallon;



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Checked H.E.K.

Charles B. Buerger
Assistant Eng.

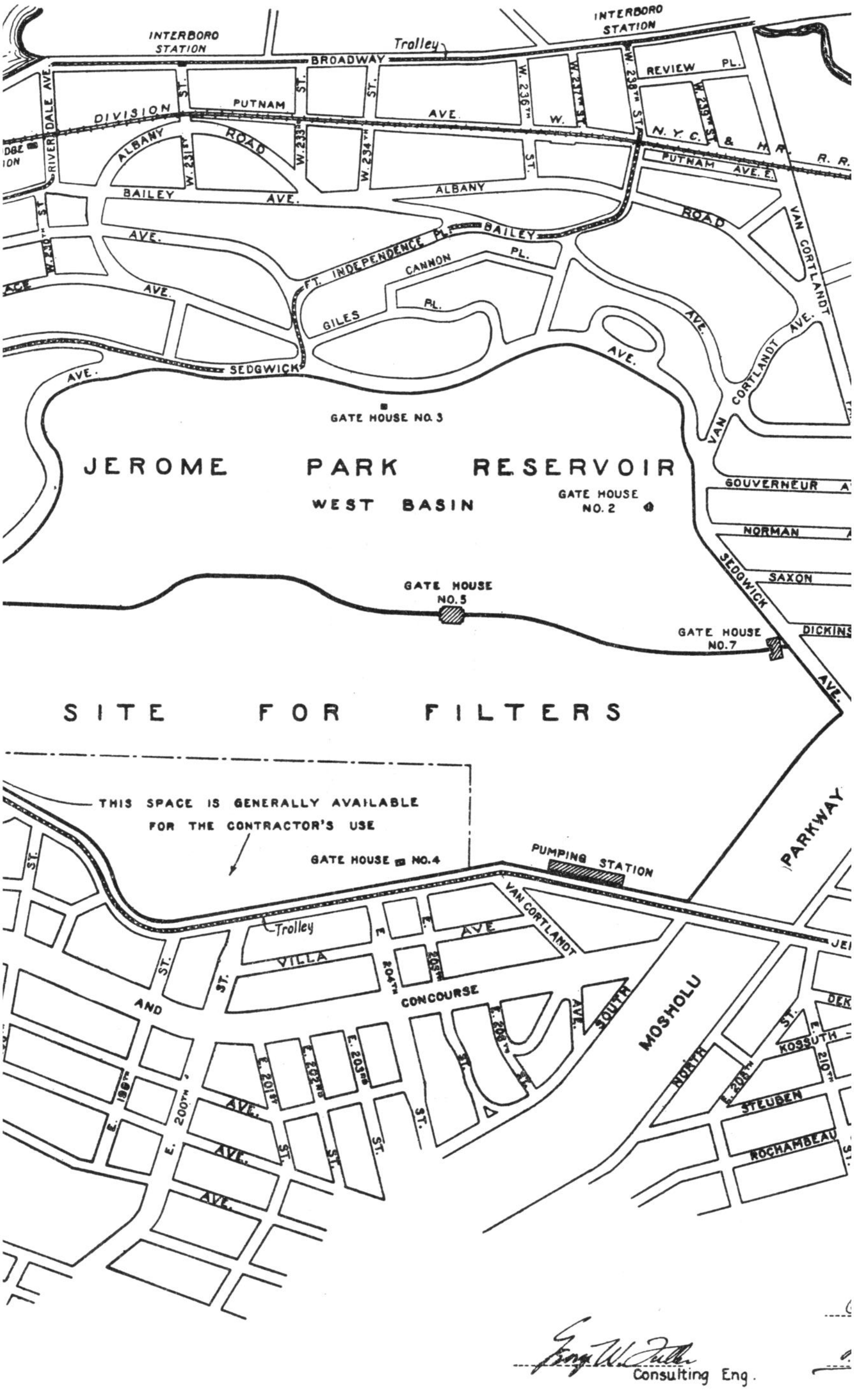

PLATE X. FILTER SITE

Sheet 3

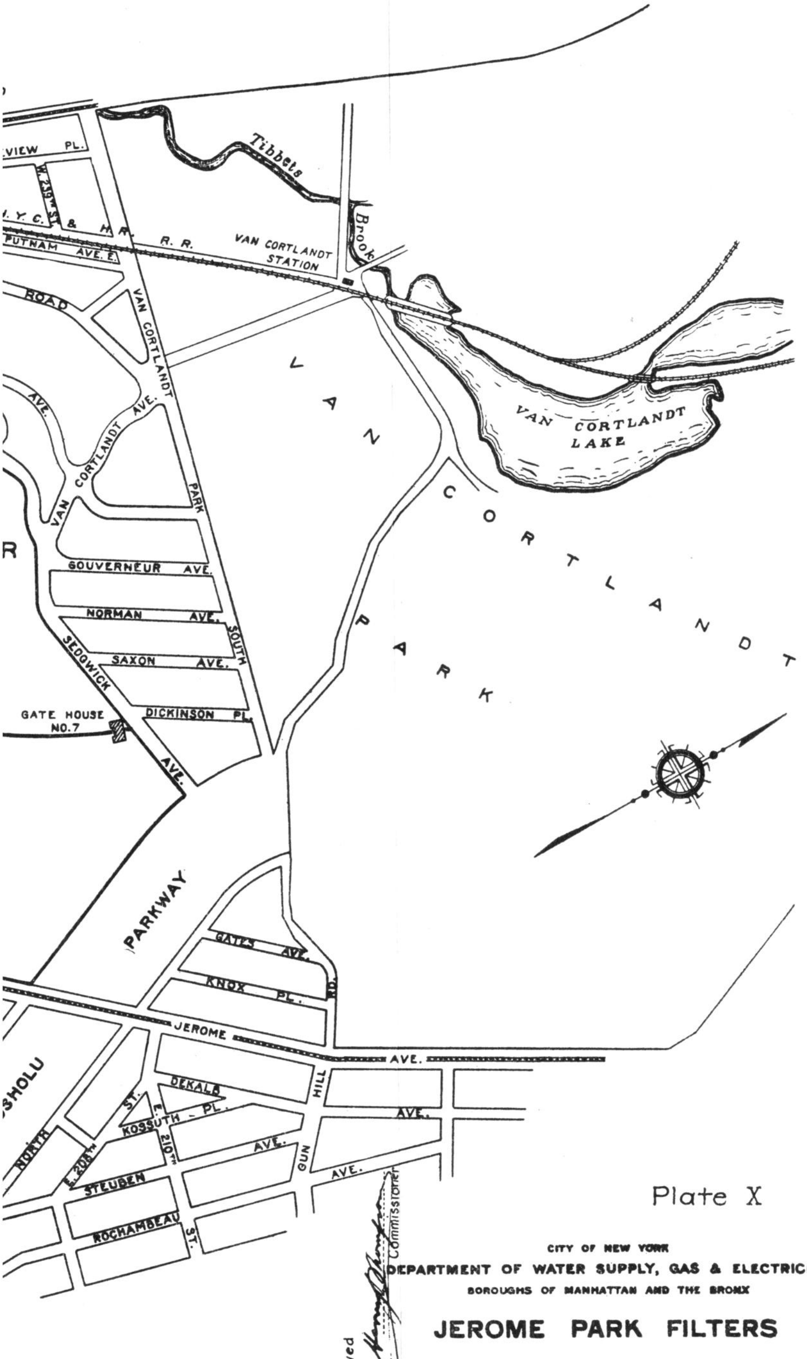

Plate X

CITY OF NEW YORK
DEPARTMENT OF WATER SUPPLY, GAS & ELECTRICITY
BOROUGHS OF MANHATTAN AND THE BRONX

JEROME PARK FILTERS

STREET MAP NEAR SITE

400 0 400 800Ft.

JUNE 1912

Approved .... Commissioner

E.G. Monahan
Division Eng

sulting Eng.

I.M. deVarona
Chief Eng

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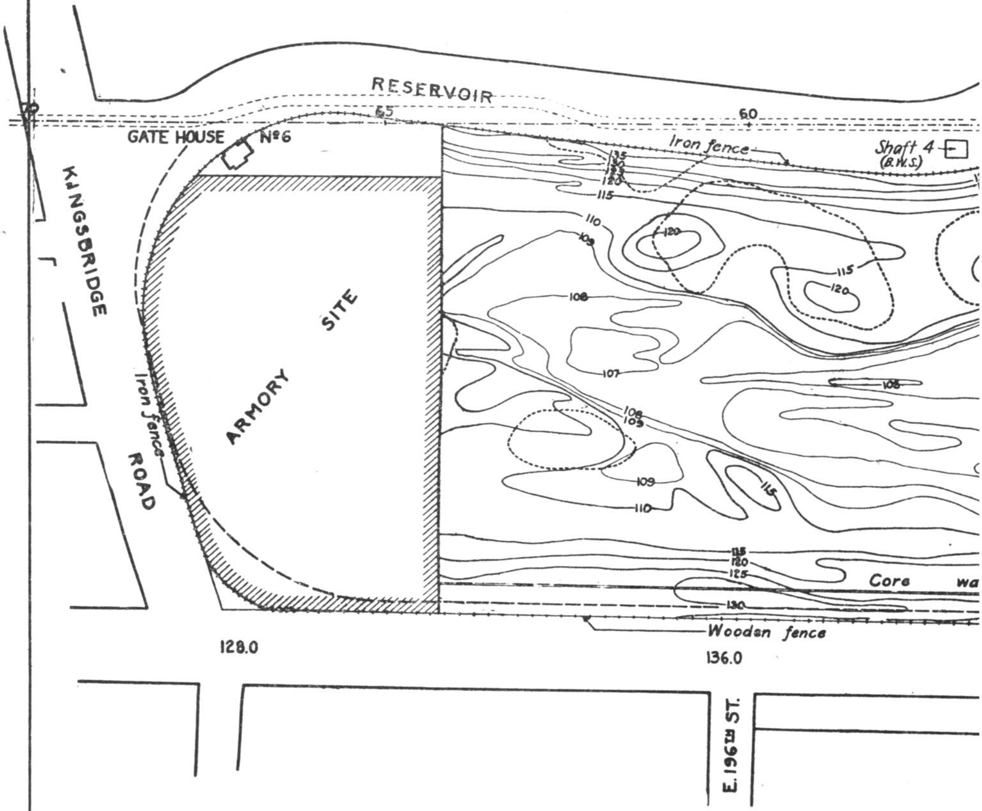
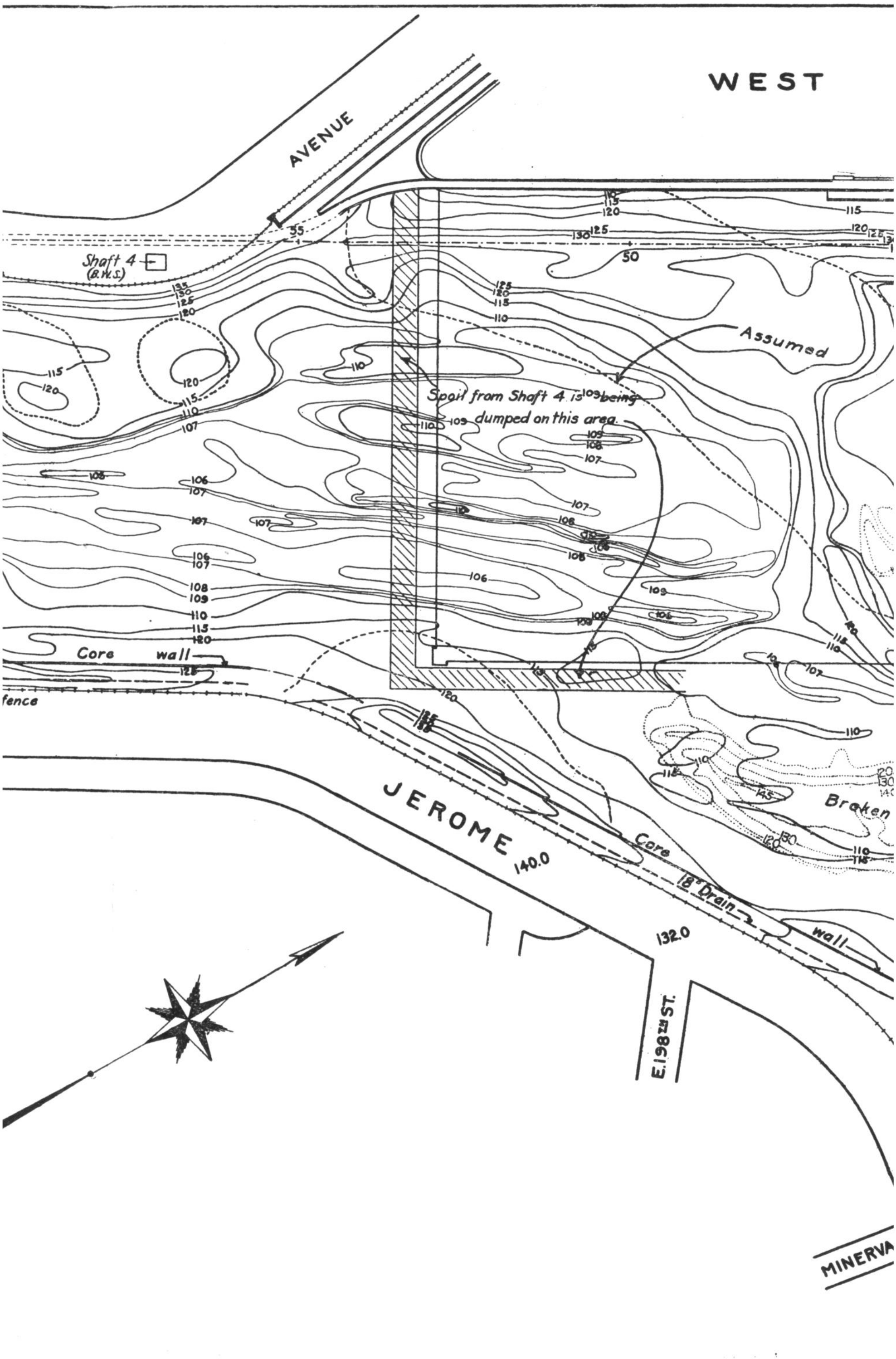


Elevations refer to Public Works datum which is 2.67 feet above U.S.C. and G.S. datum.

Drawn A.R.N.A. & W.E.K.
Traced E.K.
Checked E.f.

Charles B. Burger
Assistant Eng.


WEST
AVENUE
Shaft 4
(B.W.S.)
55
50
Assumed
Spoil from Shaft 4 is being dumped on this area.
Core wall
fence
JEROME
140.0
Core
18" Drain
wall
132.0
E.198th ST.
Broken
MINERVA

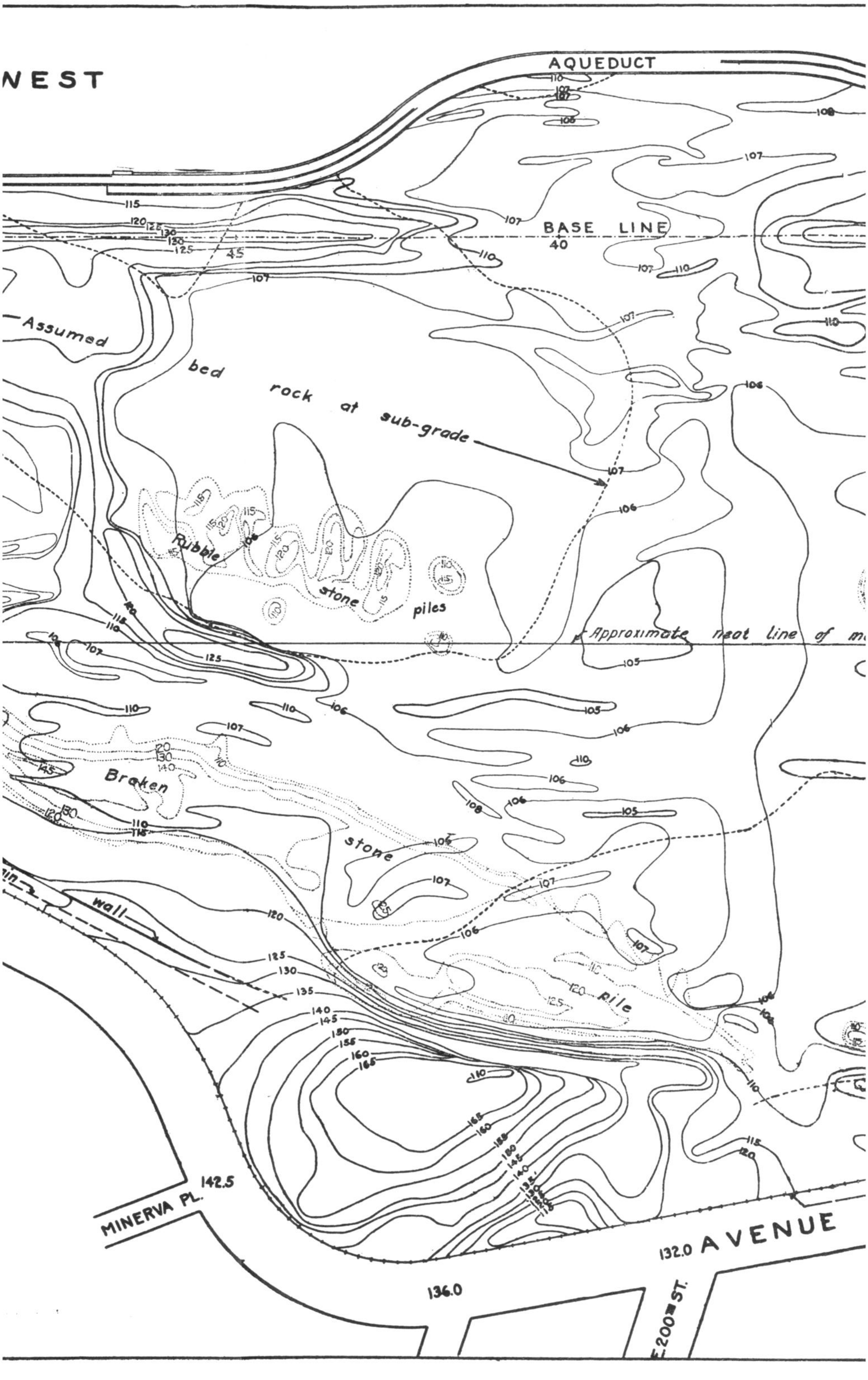
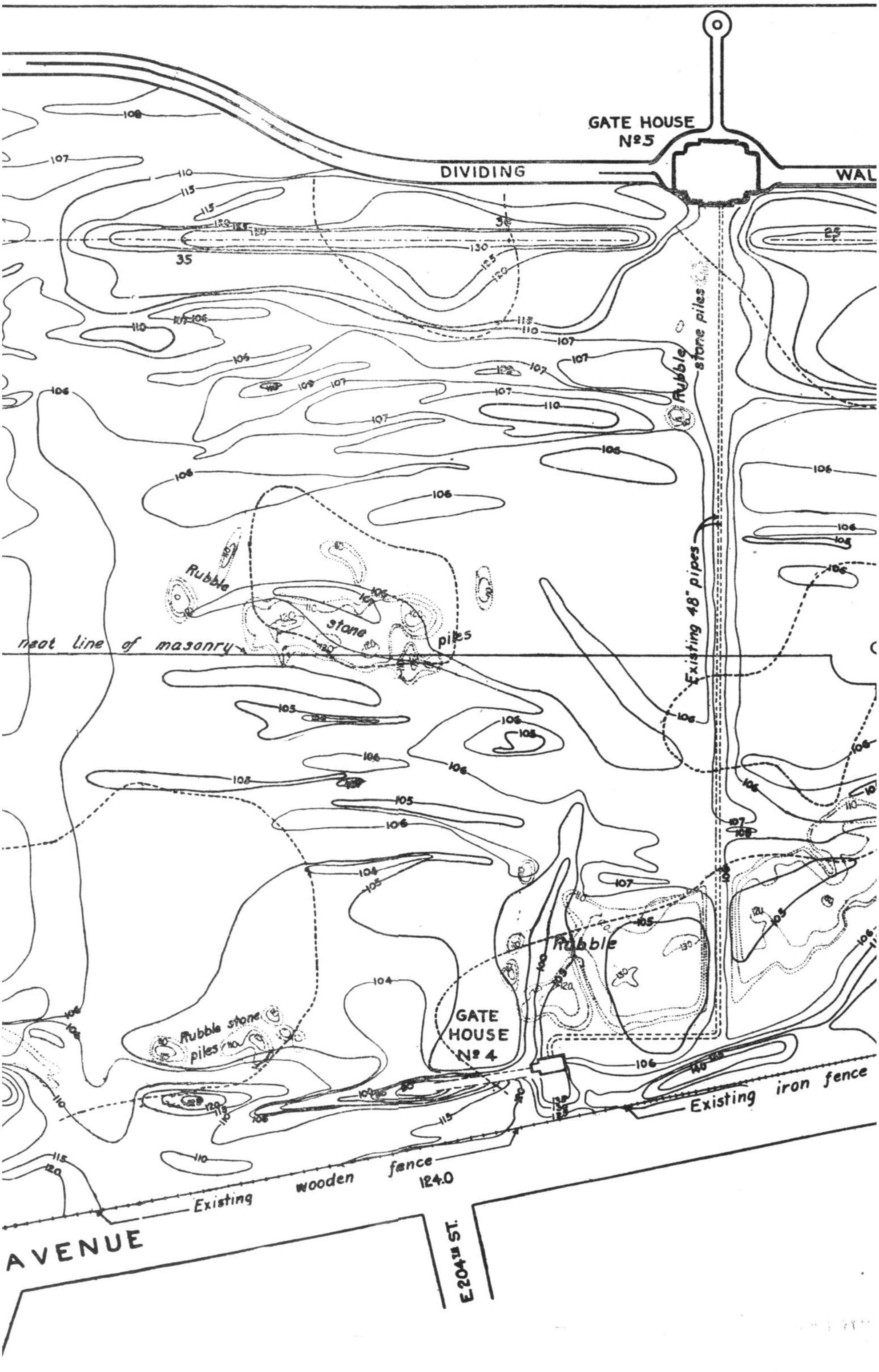
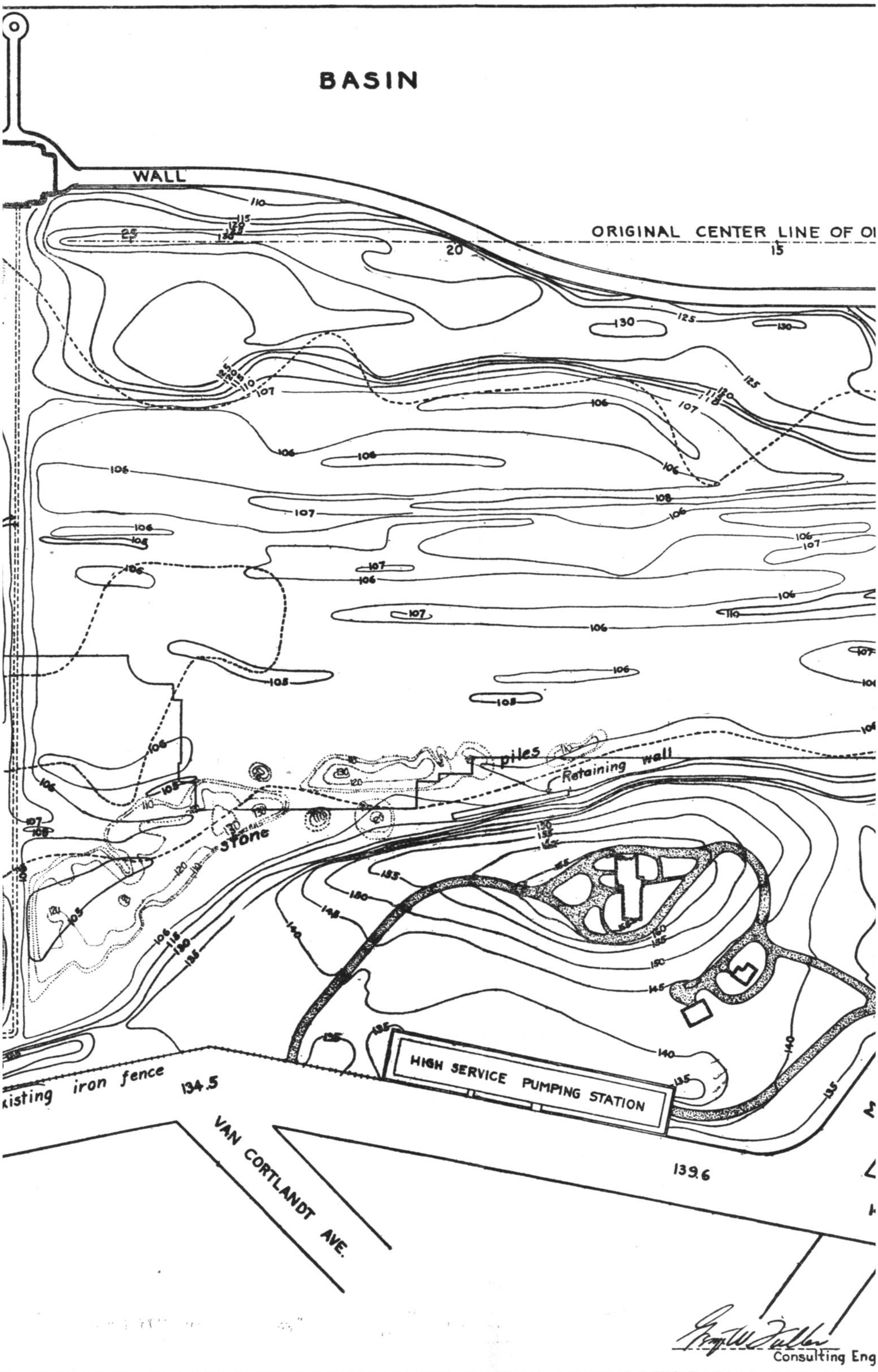


Plate XI. Topography of Fi



opography of Filter Site


BASIN
WALL
ORIGINAL CENTER LINE OF OI
20
15
110
115
125
130
106
107
108
105
140
145
150
155
piles
Retaining wall
Stone
HIGH SERVICE PUMPING STATION
xisting iron fence
134.5
VAN CORTLANDT AVE.
139.6
Consulting Eng

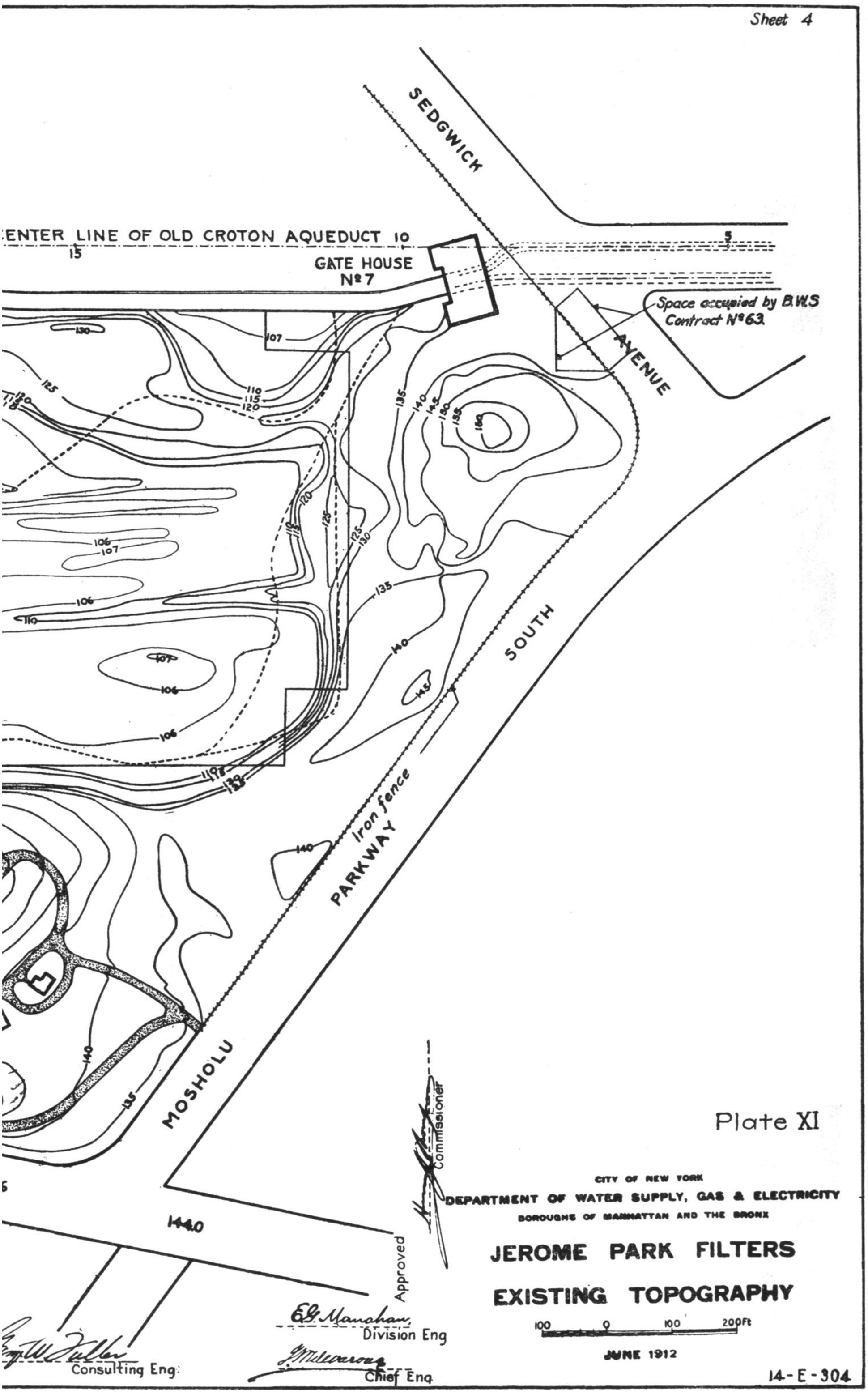


Plate XI

CITY OF NEW YORK
DEPARTMENT OF WATER SUPPLY, GAS & ELECTRICITY
BOROUGHS OF MANHATTAN AND THE BRONX

JEROME PARK FILTERS
EXISTING TOPOGRAPHY

100 0 100 200Ft

JUNE 1912

Approved Commissioner

E.G. Manahan
Division Eng

Geo. W. Fuller
Consulting Eng.

J. M. de Varona
Chief Eng.

14-E-304

TABLE 10

Croton aqueduct, hydraulic gradient

LOCATION	STATION	DISTANCE	SOFFIT OF ARCH.	HYDRAULIC GRADE LINE, AT RATES PER DAY IN MILLIONS OF GALLONS			
				293	300	310	320
		feet					
New Croton Gate House	4 + 75	0	153.53	156.92	157.87	159.36	160.86
Shaft 8, Pocantico River	453 + 84	44,909	147.58	150.37	151.05	152.05	153.05
Pocantico blowoff	495 + 30	49,055	147.03	149.76	150.42	151.36	152.32
Sawmill River Cut	732 + 72	72,797	143.85	146.30	146.80	147.48	148.20
Ardsley Blowoff	826 + 25	82,150	142.64	144.94	145.38	145.97	146.56
Shaft No. 14 A	830 + 57	82,582	142.58	144.88	145.33	145.91	146.48
Tibbet's Brook Blowoff	1121 + 25	111,650	138.73	140.62	140.91	141.16	141.46
Dunwoodie Cut and Cover	1140 + 30	113,550	138.48	140.33	140.60	140.85	141.12
Gate House 1	1266 + 18	126,143	136.78	138.52	138.67	138.76	138.86
Gate House 7	....	5,665	135.94	137.36	137.36	137.36	137.36
East Chamber Gate House 7	....	....	....	137.11	137.11	137.11	137.11
S in feet per 1,000: Main Aqueduct				0.146	0.152	0.163	0.174
S in feet per 1,000: Branch Aqueduct				0.222	0.232	0.247	0.265

Elevations given in Croton Datum which is 3.61 feet below Jerome Park Datum.

Main Aqueduct: a = 155.624 square feet
r = 3.45
c = 130.

Jerome Park Branch: a = 132.63 square feet
r = 3.145
c = 130.

soda (alternative) maximum 1.5 grains per gallon. Sterilization was to be effected by hypochlorite of lime applied at a rate of from 5 to 10 pounds per million gallons.

DECARBONIZATION

A good deal of study was given to the question of what is known as the "red water plague." The use of soft waters, particularly of waters from swampy sources, in iron service pipes usually brings into the water a large amount of red rust. This is particularly marked in hot water service pipes.

The presence of carbonic acid in quantity explains this action. An elaborate series of tests was made by the Department laboratories, details of which have been published in the 1912 Annual Report of the Department. The conclusions there arrived at are that the corrosion is directly proportional to the carbonic acid present; that alum-treated water produces practically no more rust than the Croton water untreated, mainly because the amount of carbonic acid set free is small; that it is desirable only to neutralize the free carbonic acid either with lime or soda.

It is well known, however, that complaints are more general on this score with filtered waters than with unfiltered waters. It is quite likely that this is to be explained by the action of the clean filtered water in removing existing protecting coats of deposits and keeping the iron surfaces somewhat cleaner.

To eliminate a possible source of complaint on the introduction of filtered water, it was decided to add lime or soda during the summer months when the carbonic acid content was high, and to reduce this carbonic acid to a point where no objectionable effect would be experienced.

DETAILS OF DESIGN

Plate XII shows the general arrangement of the plant as designed. The water supplied from both the old Croton aqueducts and the new Croton aqueduct is supplied at Gate House No. 7. The water can be sent directly to the east side to the filter plant, or directly to the storage basin on the west side, or else through the dividing wall south to the outlet at about station 46 + 00, delivering water at the far end of the storage basin, to create a desirable circulation.

The water from the Gate House 7 passes through a 14-foot Venturi meter with 7-foot 3-inch throat to Gate House 8.

Gate House 8 is a central control chamber, where the water may at will be sent through one-half or the whole of the mixing chamber and any or all of the settling basins. It is designed for that purpose with suitable dividing walls and thirty-four 5 by 12 sluice gates, operated by oil pressure cylinders. Plate XIII shows a plan of Gate House 8.

The mixing chamber has a capacity of 6, 200,000 gallons, or twenty-eight minutes normal flow, with nineteen turns at an average velocity of 1 foot per second.

There are five settling basins of an aggregate capacity of 82,000,000 gallons, giving a period of detention with all the basins in use of six hours, with a velocity of .40 of an inch per second.

Flushing and draining pipes and conduits are provided for both mixing chamber and settling basins.

A sixth basin is provided, with a capacity of 5,700,000 gallons for settling wash water, so that it may be refiltered at times of water shortage. This wash water is pumped at Gate House 8 back to the supply conduit.

The six basins all lead to Gate House 9 shown on the plan, similar to Gate House 8, but smaller.

The net area of the mixing chamber and settling basins was 11.6 acres, and the gross area occupied by these structures is 13.8 acres.

The coagulant is normally applied at Gate House 8 through a rubber pipe grid. Two 5-inch coagulant supply pipes lead to this point from the head house. For supplementary coagulation two 4-inch alum lines run to Gate House 9.

For emergency use one 6-inch alum pipe runs to Gate House 7 and means for dry application are provided at Gate House 7, consisting of a bronze cage or basket holding alum suspended in the current of the water.

All the basins are covered with a groined arch concrete roof and with 2 feet of earth cover.

The filters are completely separated from the settling basins as shown on Plate XII. There are 80 filters, divided into four series of 20 each, 10 arranged on each side of the operating gallery. The filters have an effective sand surface of 359 square feet per million gallons rating. A typical plan is shown on Plate XIV.

The feature of having the high water level in the reservoir 4 feet higher than the crown of the arches supporting the filters, and the necessity of adapting the design to all four possible conditions of loading, viz., filter full and empty, and basin full and empty, required a special consideration of the basin walls, and these are materially heavier than is usual. Particular care is used to reduce friction because of the small head available; pipe velocities are uniformly low; it will be noticed that inlet and outlet openings are larger than the valves, with converging or diverging connecting pipes.

The filter sand specified is unusually course, 0.60 to 0.70 mm effective size.

The plans provided for three types of strainer system under alternate bidding items.

Type A consisted of cast-iron manifolds, cast-iron laterals with brass strainer cups for washing at the rate of 9 gallons per minute per square foot of sand surface, and a separate air system for air wash through cast-iron manifolds, and brass laterals, at the rate of 4 cubic feet per minute per square foot of sand surface.

Type B provided for the application of both air and water through the same system, using the Williamson strainer.

Type C consisted of concrete channels and perforated brass plates for applying water only at the rate of 15 gallons per minute per square foot of sand surface. The sand and gravel were separated by a brass wire screen.

Table 11 following gives the working velocities through the various parts of the three strainer systems for filtration and washing.

Wash water is to be stored in a reservoir on the hill top and intended to be supplied from the Catskill water system by gravity, and in case of emergency from the existing service pumping station.

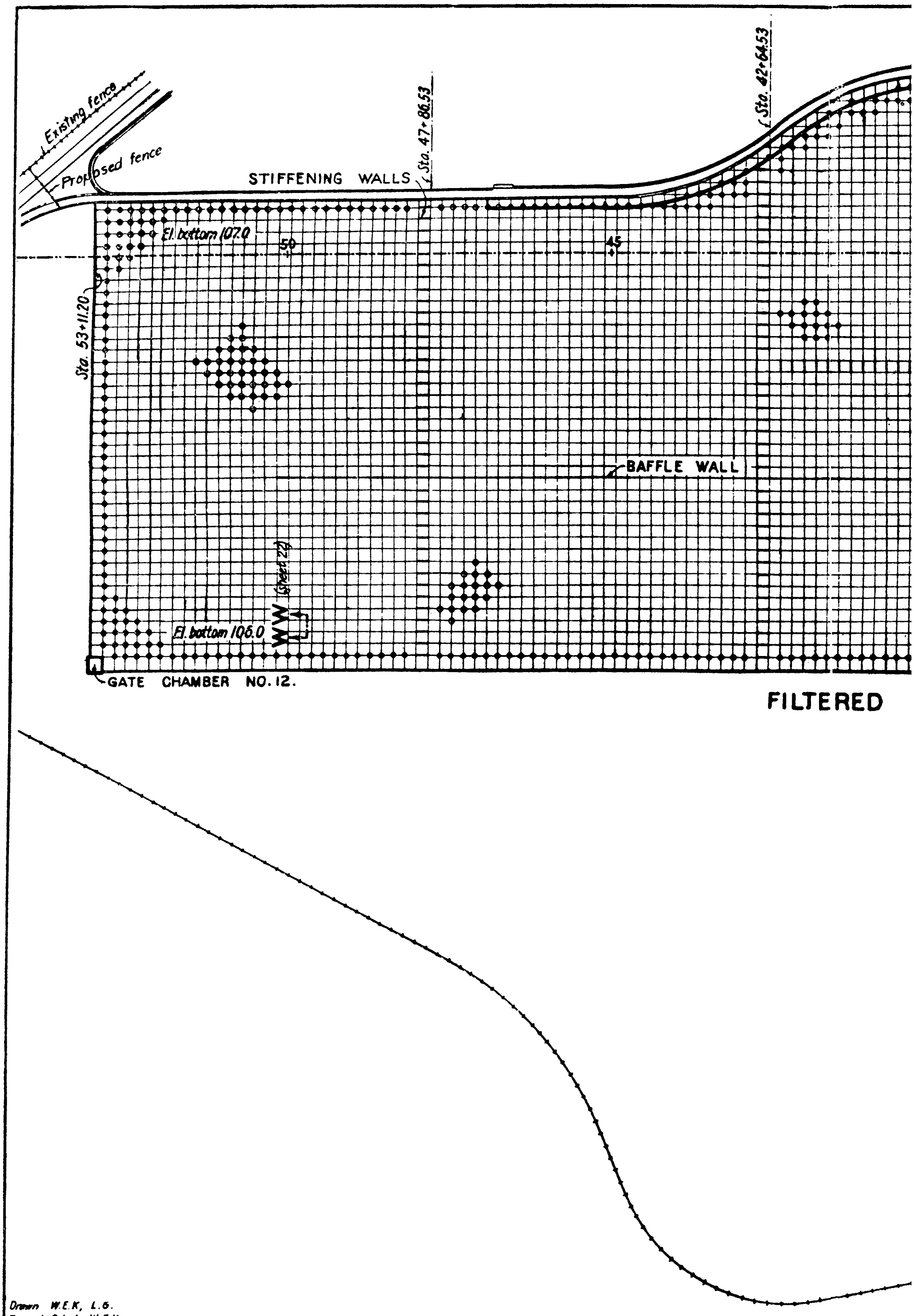
On leaving the filter galleries, the filtered water is treated with hypochlorite of lime.

The net filtering area of the plant is 2.7 acres; the gross area occupied is 4.5 acres. The capacity of the reservoir under the filters is 14,400,000 gallons.

The south end of the four filter galleries is connected by a three-story building to be used as a laboratory for the department.

Plate XV shows a picture of the architectural treatment of the south facade; the remainder of the buildings were designed to harmonize with this front. Messrs. Hiss and Weeks were architects for this design.

The water, after receiving hypochlorite treatment, passed for a five-minute period through channels at a 1-foot per second velocity and then to Gate House 10 where, when needed, lime was to be applied.



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Checked A.U.R.
Charles B. Burger Assistant Eng.

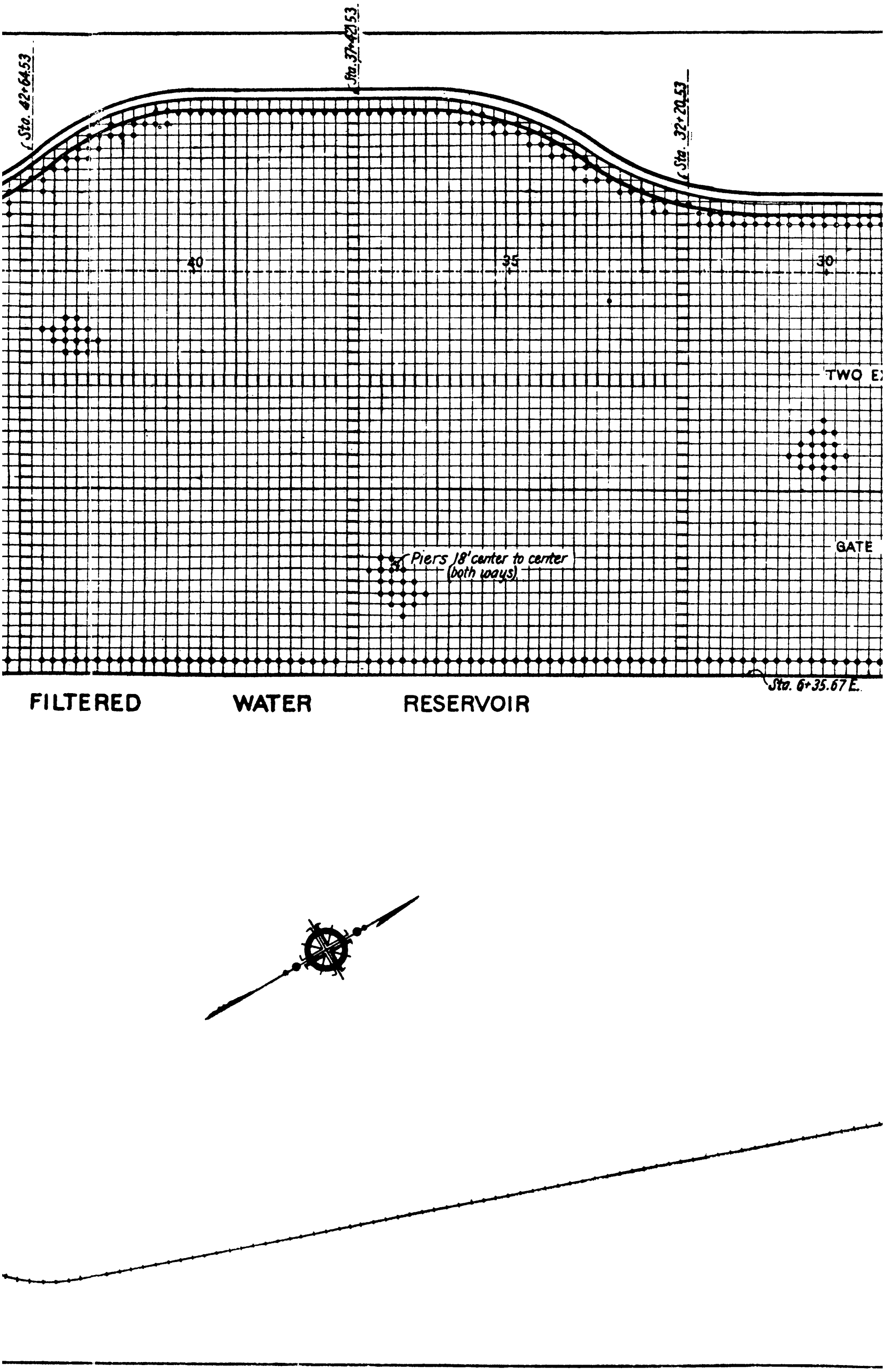
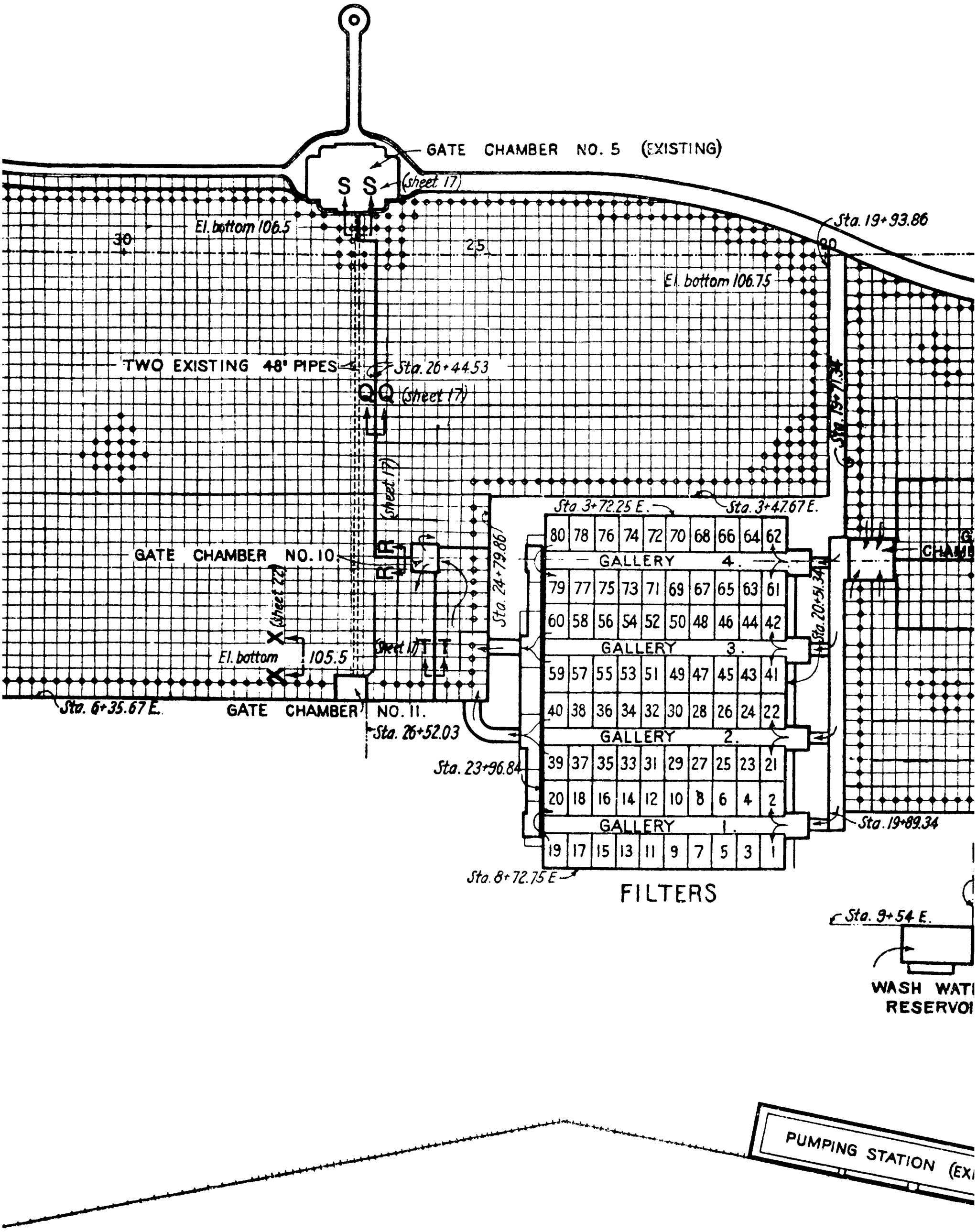


Plate XII. General Arrangem



The elevations shown for the bottoms of the reservoirs are subject to modification depending upon the character of material encountered

Geo. W. Fuller
Consulting

NERAL ARRANGEMENT OF FILTER PLANT

Sheet 2

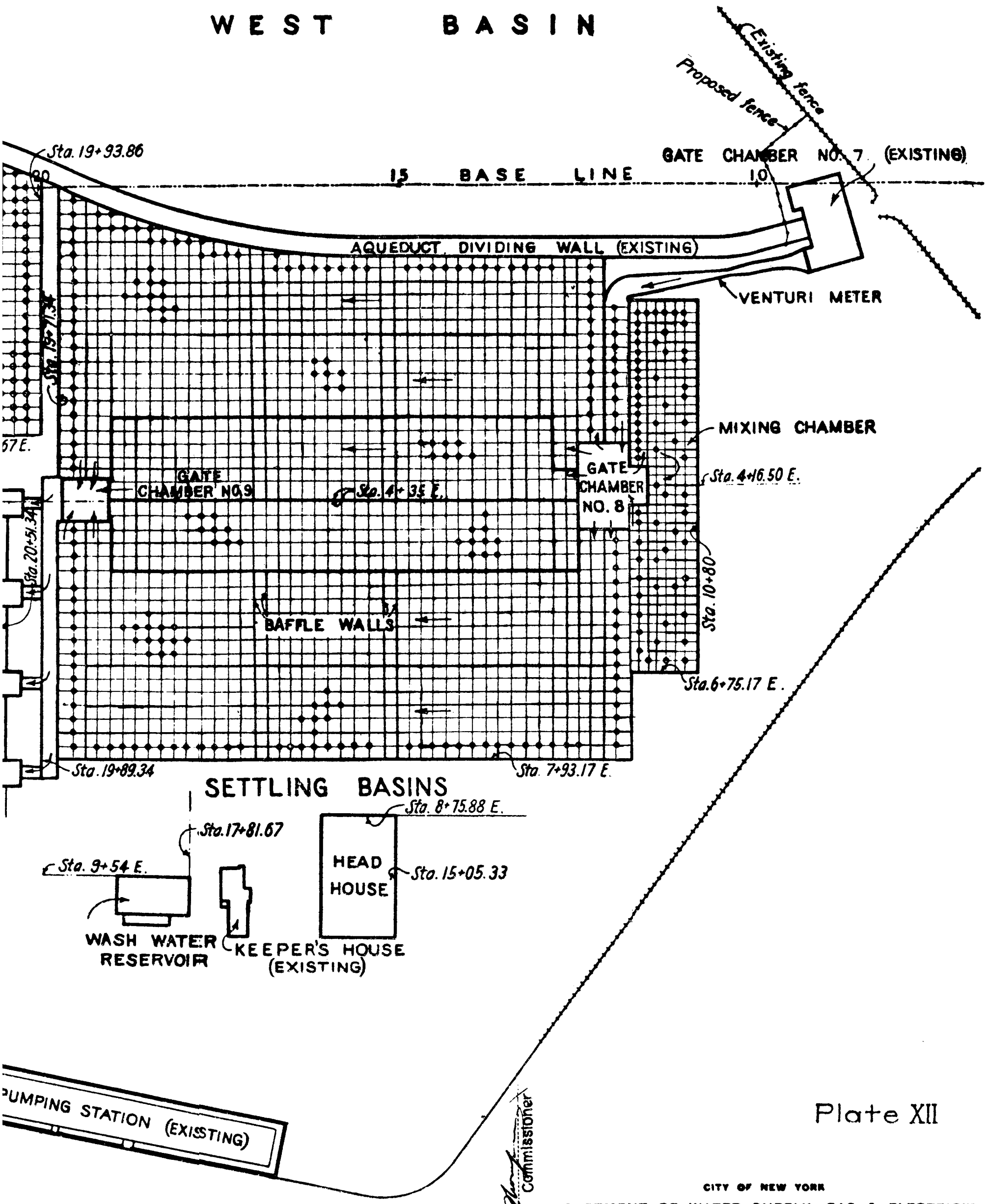


Plate XII

Approved

Commissioner

CITY OF NEW YORK
DEPARTMENT OF WATER SUPPLY, GAS & ELECTRICITY
BOROUGHS OF MANHATTAN AND THE BRONX

JEROME PARK FILTERS
GENERAL ARRANGEMENT

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JUNE 1912

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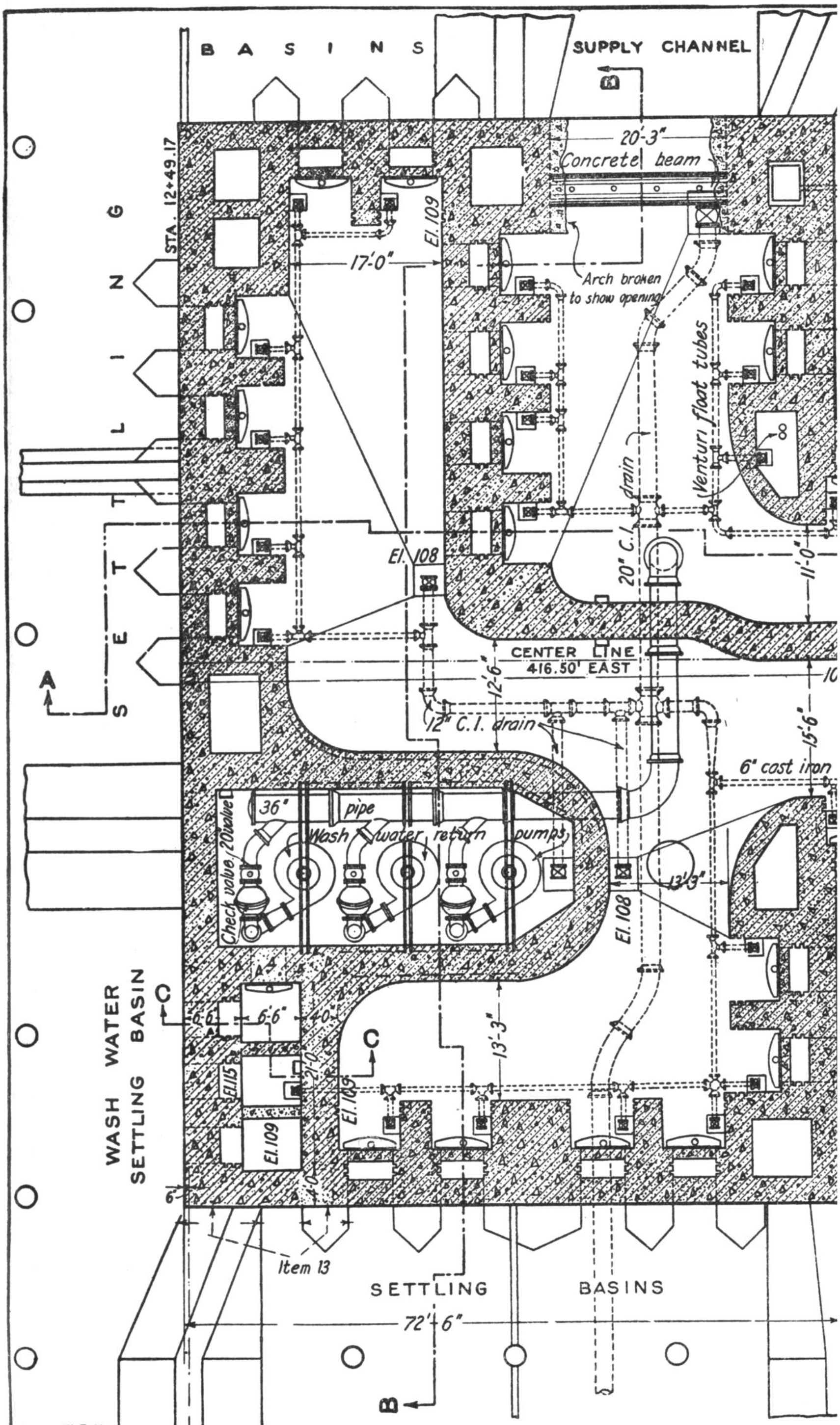
ding

E.G. Manahan
Division Eng.

Geo. W. Fuller
Consulting Eng.

Chief Eng.

16-E-302



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Checked C. J. S.
Charles B. Burger
Assistant Eng.

SECTIONAL PLAN EL. 135.0

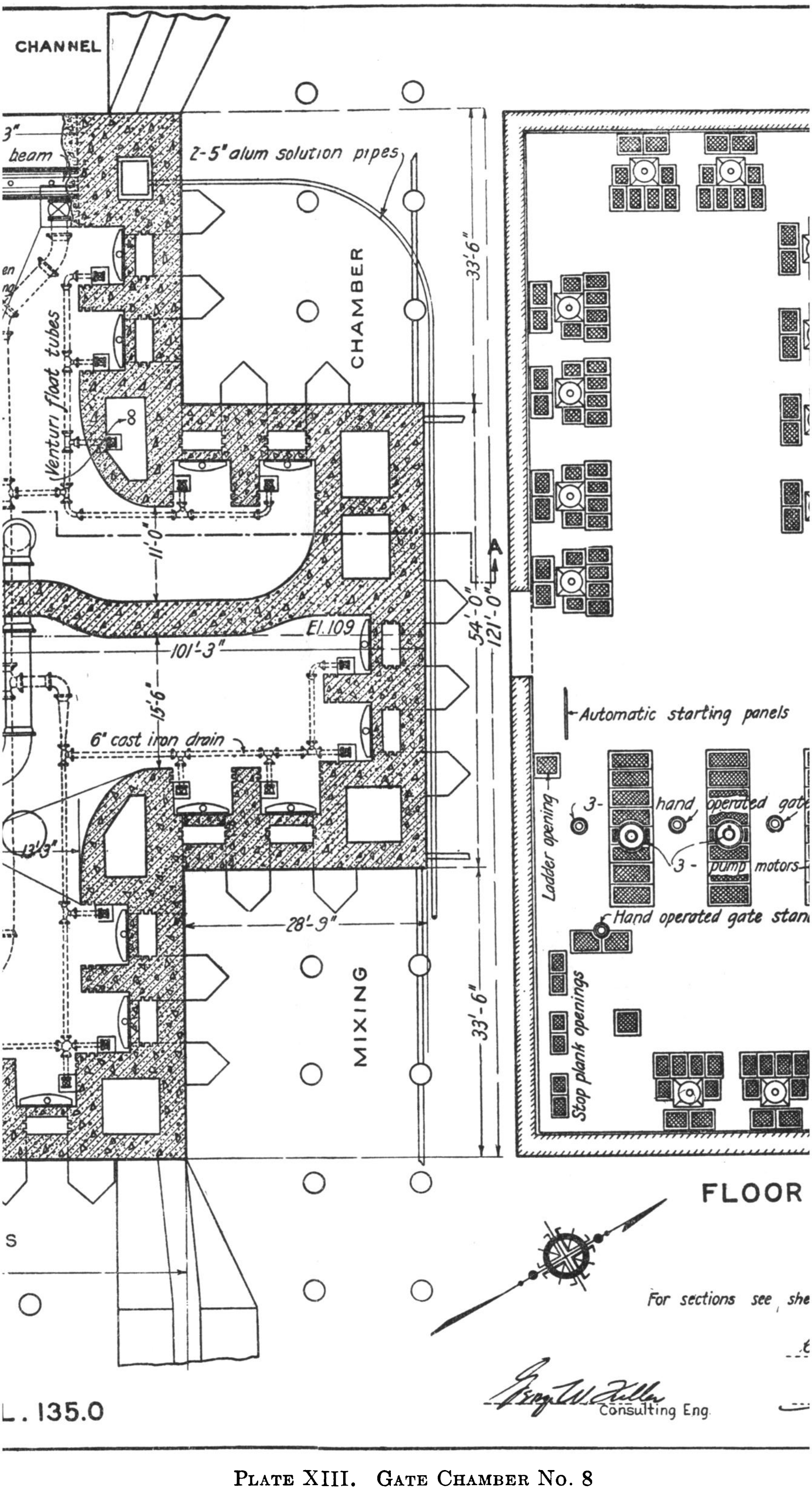

PLATE XIII. GATE CHAMBER NO. 8

Sheet 32

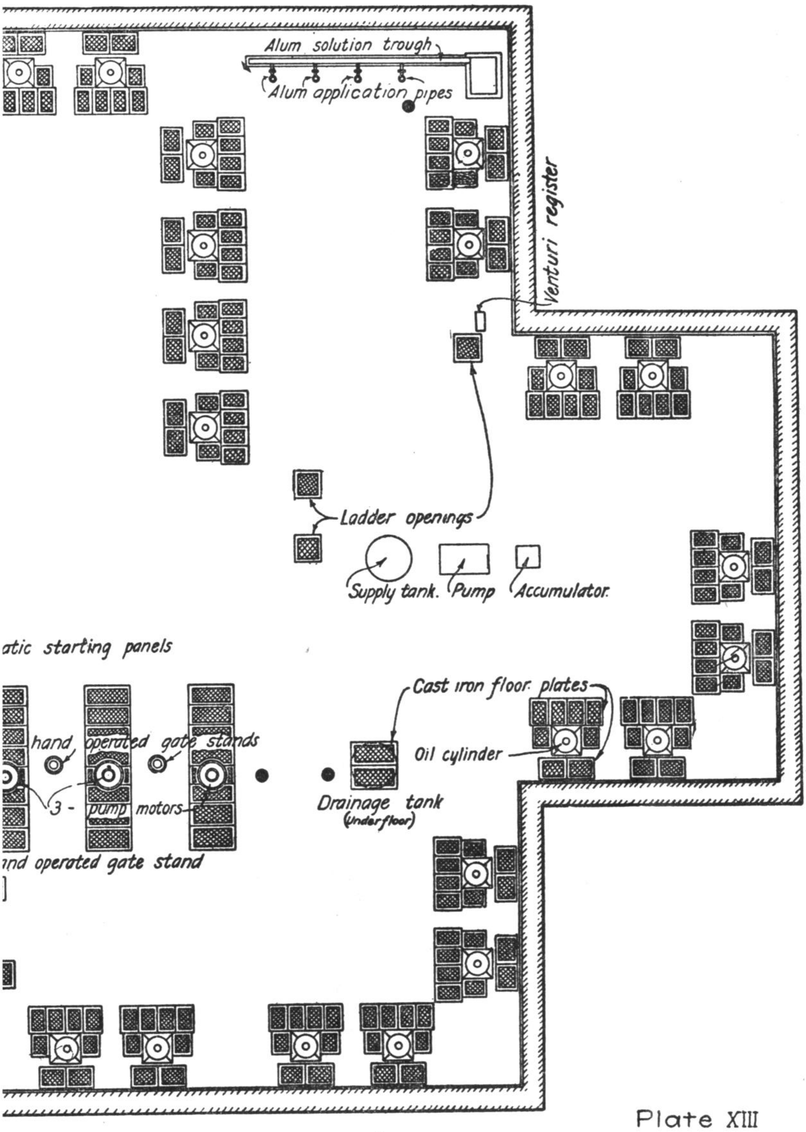

Plate XIII

FLOOR PLAN

For sections see sheet 33

E.G. Manahan
Division Eng

sulting Eng.

I.M. de Varona
Chief Eng.

Approved
Commissioner

CITY OF NEW YORK
DEPARTMENT OF WATER SUPPLY, GAS & ELECTRICITY
BOROUGHS OF MANHATTAN AND THE BRONX

JEROME PARK FILTERS

GATE CHAMBER No 8

2 0 2 6 10 14 18 22 Ft

JUNE 1912

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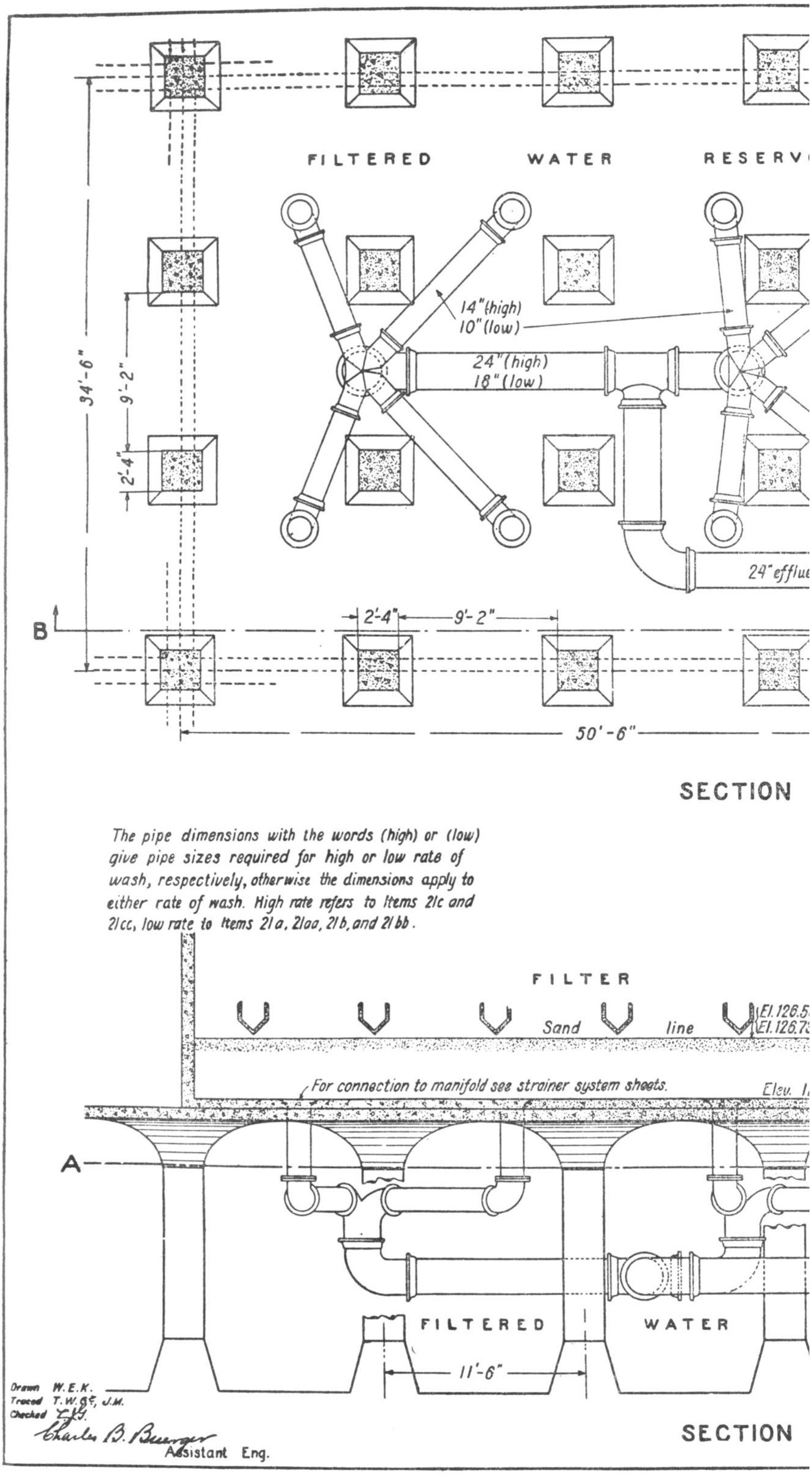
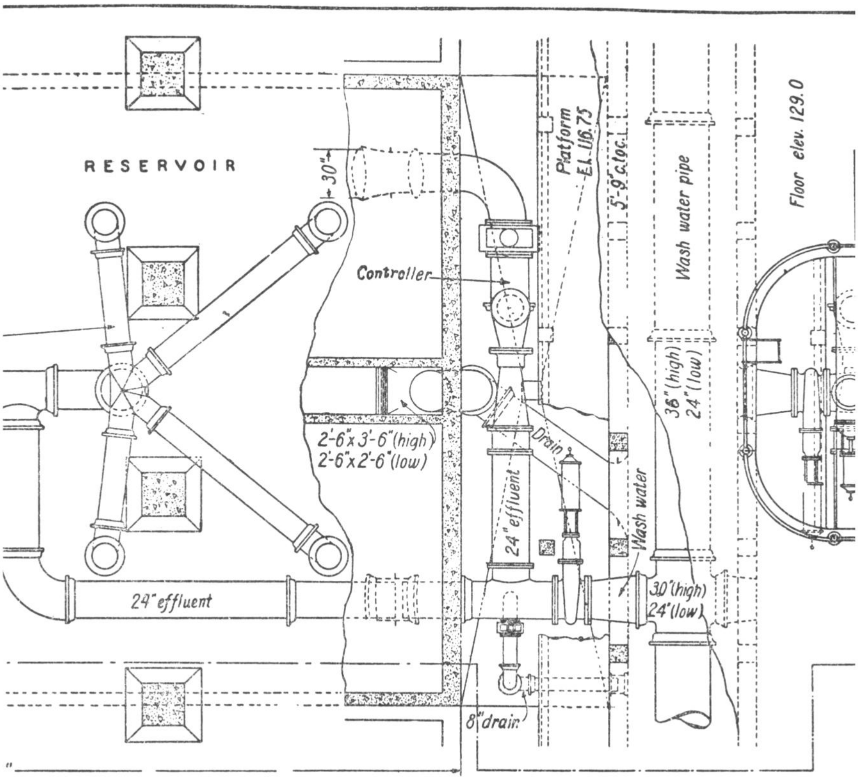


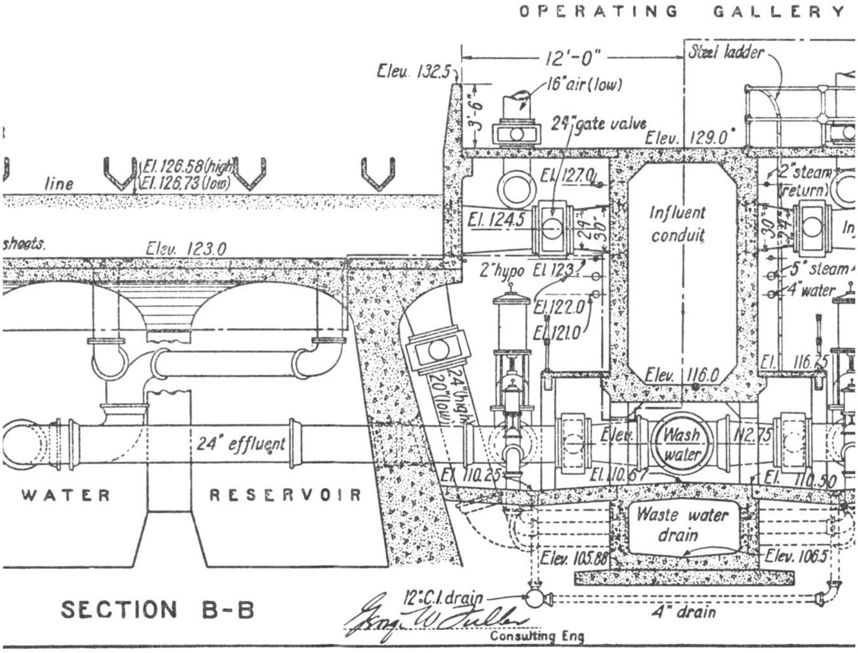
The pipe dimensions with the words (high) or (low) give pipe sizes required for high or low rate of wash, respectively, otherwise the dimensions apply to either rate of wash. High rate refers to Items 21c and 21cc, low rate to Items 21a, 21aa, 21b, and 21bb.

Drawn W.E.K.
Traced T.W.G., J.M.
Checked L.J.G.
Charles B. Buerger
Assistant Eng.

PLATE

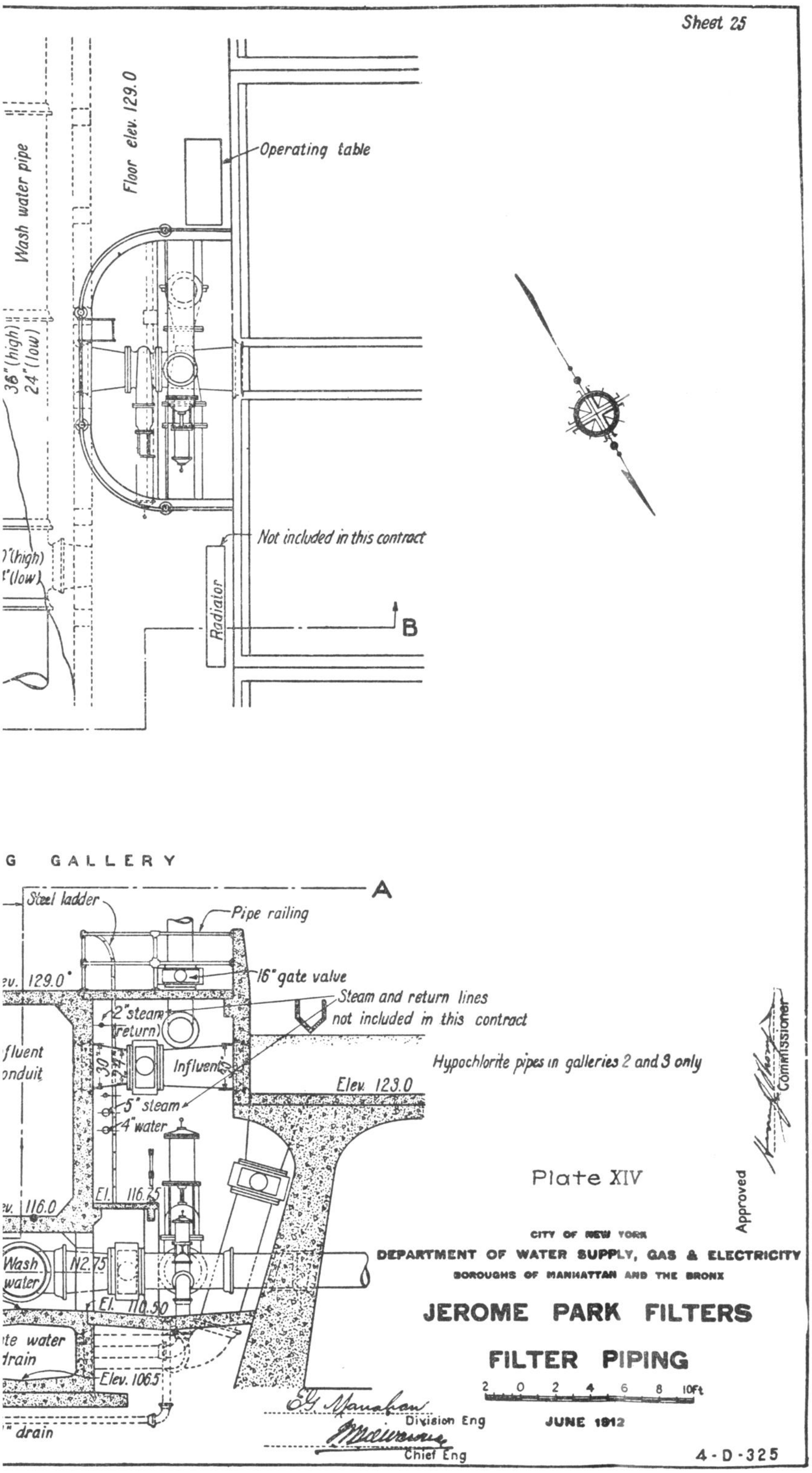


SECTION A-A



SECTION B-B

PLATE XIV. SECTION OF FILTER AND FILTER GALLERY



Approved

Commissioner

Plate XIV

CITY OF NEW YORK

DEPARTMENT OF WATER SUPPLY, GAS & ELECTRICITY

BOROUGHS OF MANHATTAN AND THE BRONX

JEROME PARK FILTERS

FILTER PIPING

E.G. Manahan
Division Eng

Chief Eng

JUNE 1912

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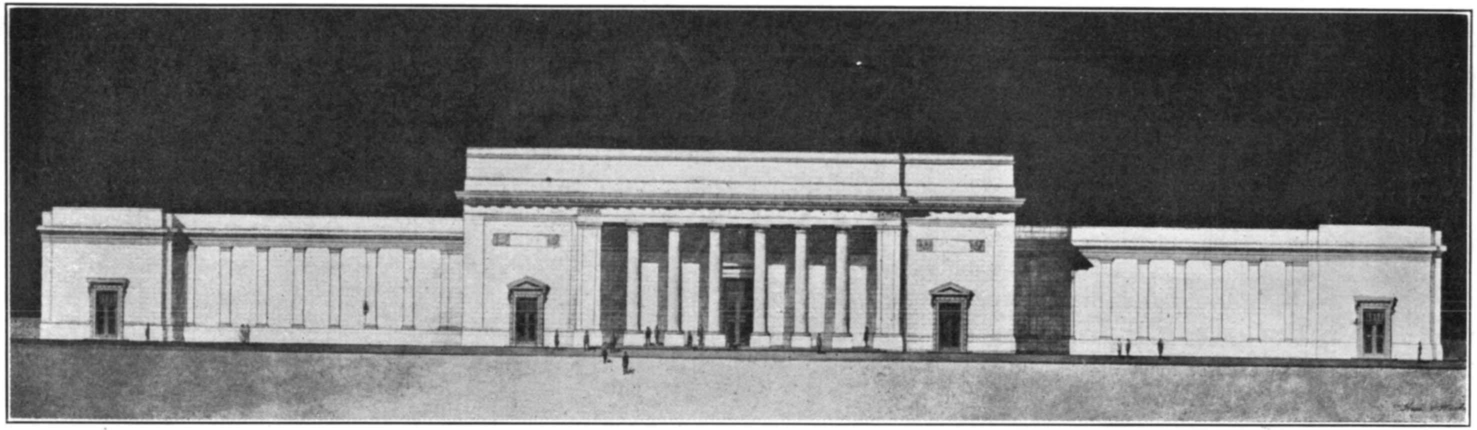

Plate XV. South Elevation of Filter House

TABLE 11

Jerome Park filters. Strainer and air system, working velocities feet per second

	FILTRATION	WASH	AIR (FREE)
Type A			
Through sand	0.00443	0.02	0.0668
Strainer holes, or air holes	1.50	6.75	260.
Strainer neck	2.20	10.00	....
Laterals	.71	3.18	86.
Manifold	1.11	5.00	79.
10-inch supply	1.46	6.60	....
18-inch collector	1.80	8.15	....
24-inch main	2.03	9.17	....
16-inch air main	....	....	68.8
Type B			
Through sand	.00443	0.02	.0668
Strainer holes	1.55	7.10	23.4
Strainer neck	2.15	9.70	360.
Laterals	.58	2.60	8.68
Manifold	1.11	5.00	8.32
10-inch supply	1.46	6.60	....
18-inch collector	1.80	8.15	....
24-inch main	2.03	9.17	....
16-inch air main	....	....	68.8
Type C			
Through sand	.00443	.0333	
Strainer holes	1.41	10.8	
Laterals	.26	1.98	
Manifold channel	.40	3.08	
14-inch supply	.73	5.60	
24-inch collector	.99	7.61	
24-inch main	2.00	15.2	

The filtered water reservoir was a covered two section basin of the usual type of a net area of 53.55 acres, a gross area of 55.13 acres and a capacity of 356,000,000 gallons.

The water from the filtered water basins passed through Gate House 5 to a shaft connecting with the pressure tunnel to the city.

The head house was located on the side of the existing hill, with elevations suitable to feed alum and hypochlorite by gravity from the feed boxes. A valuable novelty of design was the arrangement which permitted incoming trucks loaded with chemicals to enter the building at the highside so that they could discharge their contents directly into the storage bins, from which the chemicals were discharged into the mixing boxes below, and no elevator was required. The capacities allowed for various chemicals are:

	cubic feet per million gallons per day
Alum storage and lime or soda storage	190
Alum solution tanks	108
Lime suspension tanks	42
Hypochlorite solution tanks	34

BIDS RECEIVED

The completed plans and specifications were submitted to the Board of Estimate on June 25, 1912, and were referred to their Chief Engineer, Mr. Nelson P. Lewis, and to the Principal Assistant Engineer of the Department of Finance, Mr. Chandler Withington. The report of these gentlemen is given below.

> On the 23d instant you handed us the plans, contract and specifications for the Jerome Park filters, with a request that we examine them carefully and report to you as to their adequacy and sufficiency to secure the desired result, namely, the proper filtration of Croton water by a system of mechanical filters.
>
> We have carefully examined the plans, the contract and the specifications, and have conferred with the officers of the Department of Water Supply, Gas and Electricity and the Engineer who was in immediate charge of the preparation of the plans, all of whom have readily given us any information we desired.
>
> We have suggested a few minor changes in the form of contract in order to remove any ambiguity and to eliminate what might prove to be slight inconsistencies. These changes the Commissioner of Water Supply has approved and has incorporated in the form of contract. We have also suggested certain modifications in the specifications with a view to making them more definite, and have advised certain changes in some of the incidental work, such as the building of roads, which we believe would give better results without any increase in cost. These changes met with the approval of the Engineers and have also been incorporated in the form of contract and specifications which we herewith submit.
>
> In general, the specifications are in our judgment admirable in form and arrangement and exceptionally free from ambiguity, and we can see no reason why they should not be approved by the Committee.

The plans and specifications for the first contract were printed and advertised and after some delay bids were received on January 23, 1913. Nine bids were received ranging from $5,139,015 to $6,752,000. The engineers' estimate was $5,916,700.

A comparison of prices on some of the more important items is given in Table 12.

TABLE 12

Contract prices

ITEM NO.	DESCRIPTION	UNIT	ENGINEERS' ESTIMATE	AVERAGE BID	LOW BID
1	Earth excavation.......	cu. yd.	$0.70	$0.87	$0.74
2	Foundation excavation...	cu. yd.	1.00	1.42	.84
3	Roch excavation.......	cu. yd.	1.75	1.53	.98
8	Puddle.......	cu. yd.	4.00	3.37	3.20
11	Foundation concrete....	cu. yd.	7.75	6.80	6.50
12	Pier and vaulting concrete.	cu. yd.	9.50	8.81	7.90
13	Wall concrete..	cu. yd.	7.75	7.43	6.50
14	Thin reinforced concrete.......	cu. yd.	13.50	12.84	10.60
20	Main drain...	lump	50,000.00	70,718.44	65,000.00
21	Filter equipment.......		1,024,000.00	1,343,695.00	1,043,000.00
22	Cast-iron pipe..	ton	45.00	46.00	39.00
23	Specials......	ton	90.00	87.78	85.00
25	Sluice gates...	lump	100,000.00	91,056.00	82,000.00
26	Gate valves...	pound	.10	.102	.09
	Total....		$5,916,700.00	$6,058,354.00	$5,139,015.00

NOTE: Concrete prices are affected by the presence on the ground of considerable suitable broken stone and the availability of excavated stone for this purpose.

OPPOSITION TO THE PROJECT

At this time a strong opposition to the project manifested itself. The controversial features have been admirably covered in the articles in the *Engineering News* of the dates May 22, May 29, and June 5, 1913, and need be referred to at this place only briefly.

A small number of detailed criticisms were made of the plans and specifications. As these have been examined and unreservedly approved by more than a dozen competent and disinterested engineers including the first Board of Consulting Experts, the Board of Advisory Engineers to the Stock Budget Committee of the Board of Estimate and Apportionment, the Chief Engineer of the Board of Estimate, and the Principal Assistant Engineer of the Department of Finance, these criticisms may be summarily dismissed. Criticism was also made of the site selected, and the method of filtration recommended.

The whole problem was referred by the Board of Estimate to an advisory commission of engineers, composed of Messrs. Nicholas S. Hill, Jr., Consulting Engineer; John H. Gregory, Consulting Engineer; E. P. Goodrich, Consulting Engineer to the President of Manhattan; Amos L. Schaeffer, Consulting Engineer to the President of the Bronx; John H. Frazee, Assistant Engineer, Department of Finance.

The commission investigated all phases of the matter for three months, and in April, 1913, submitted two reports, the majority report by the first four members listed above, and the minority report by Mr. Frazee, the Comptroller's assistant.

The majority report may be briefly abstracted by the following quotations:

> *Quality of Croton water.* As at present delivered to the consumer, the Croton water would be characterized by the water analyst as noticeably colored and slightly turbid, at times quite turbid; at other times containing numbers of microscopic organisms with an odor persistently vegetable and occasionally aromatic, grassy or even fishy; reasonably soft; a good boiler water and generally satisfactory for industrial purposes; ordinarily safe but at times sufficiently polluted to indicate the possible danger of infection from water borne diseases.
>
> Evidence of the unattractiveness of the Croton water as supplied to the consumer is found in the large number of local filter plants and in the common use of bottled water.
>
> This condition (of pollution) suggests a potential danger which is a serious menace to any community.
>
> The value of long storage is thus evident. Rainfall and runoff records show that in times of flood the storage in Croton Lake is only sufficient to provide for a retention of the water flowing therein for from 10 to 15 days. As the time required for the water to flow through the aqueduct from Croton Lake to New York may be measured in hours, the period of detention in times of flood is not sufficient to give security against the introduction of an infected water into the City of New York, provided infection exists on the watershed.
>
> The typhoid fever statistics of New York indicate that the Croton water is a reasonably safe supply from the sanitary viewpoint, except possibly for short intervals, as indicated by the typhoid outbreak in 1907.
>
> *Germicidal treatments.* Hypochlorite of lime has been found to be less efficient in the treatment of raw water than filtered water, except raw waters in which there is little or no organic matter. When applied to raw water with an appreciable organic content, larger doses must be used because enough must be applied to combine with the organic and other matters in the water which are capable of rapid oxidation in its presence, and still leave enough excess to perform its germicidal function. The amount of organic matter in many waters

fluctuates rapidly from day to day, and even from hour to hour, and the difficulty of regulating the dose of hypochlorite to meet these fluctuations probably accounts for the incomplete sterilization of raw water.

Jerome Park filters. The location of the proposed filter plant in the east basin of the Jerome Park reservoir has been found to be the *best* location for the installation of the plant.

The mechanical filtration plant, as specified in the plans of the Water Department, in contradistinction to the slow sand or modified sand filtration plant, is in the opinion of the commission the best to install.

The detail design and general construction of the filter plant as proposed are in accord with modern practice, and are carefully and well executed. The specifications are reasonable and sufficient, and have developed competition, as shown by the number of bids received for the construction of the filters.

The Water Department estimates that the total cost of construction will be $7,727,000. Independent estimates prepared by this commission check within 6 per cent of the total cost of $7,727,000.

It (the annual cost of filtration) will amount to about ¾ of a cent per $100 in the tax rate.

Offsetting these costs will be the saving effected by numbers of property owners who are now required to filter, or otherwise treat, the water supplied to them by the City of New York. It is a recognized fact that the great majority of hotels and some apartment houses, as well as many private residences and office buildings, resort to local filtration of the Croton water. In addition to these costs, some taxpayers bear an indirect burden due to the purchase of bottled water for drinking purposes, a practice which is very common and may continue to some extent even after filtered water is introduced.

It is the opinion of this commission that the filtration of the Croton water supply is not imperative, but that it is highly advisable to filter the water at this time both with a view to improving the physical quality and as a safeguard against potential danger, and we so recommend with the exception of one member dissenting.

The dissenting report of Mr. Frazee was to the following effect:

I am of the opinion that it would be as satisfactorily efficient at this time, and far more economical, to strike at the sources of trouble, some of which were recognized as existing ten years ago, but toward the abatement of which nothing has been done.

The advancement of sanitary and medical science in recent years in the development of this treatment (hypochlorite application) and the inocculation against typhoid, tend strongly to discount the conjectural possibility of future outbreaks pending delay and particularly so if the polluting sources known to exist in part and to be indicated are abated.

The factors of bacterial content, which may affect the health, and of color and turbidity, taste and odor, harmless and offensive in the aesthetic sense only, all exceed at times the standards set by experts for the filtered standard. All these undesirable features are intensified beyond the necessities by the condition existing within the city and on the Croton watershed.

Water is cumulatively affected by passing through the Central Park reservoirs, through mains more or less obstructed by sediment, vegetation and organisms, to be finally stored in house tanks on the higher structures, which are pumped full at night and drawn from in the daytime.

The power of the State Board of Health should be invoked, or legislative action be sought, to compel the railroads to use special unleakable sanitary equipment during the time of crossing this territory (the Croton watershed). In any case protective pans should be installed over all waters.

It is to be noted, further, that at least certain of the highway bridges crossing tributary water have the ordinary type of plank flooring, through the crevices of which B. coli from the excreta of farm animals can readily pass or be washed by rains.

This wash water (from farming lands, highways, etc.) might be isolated by dikes and be led to points where sedimentation could be effected or preliminary filtration had.

Reforestation, shrub and grass planting to give a sand binding, absorbent root system and to provide a screen from highway dust, will ameliorate these conditions.

The Commission on Additional Water Supply noted the improvement to be effected by the removal of sediment (from swamps and shallow flowage), and the draining of the swamps. Nothing has been done in relief, whereas dredging or filling in would effect beneficial results.

But the responsibilities warrant strengthening in numbers that a system of patrol can be instituted by tests in accordance with an uptodate sanitary map's requirements. The sensitiveness of scent of dogs would warrant their training as auxiliaries.

Mr. Frazee further figures on the financial advantages of delay. He assumes that the land proposed as a site would be sold; that 10 lots to the acre would be taxed, bringing a tax revenue of $330,000 per year; that $3,000,000 would be obtained from the land, that a saving of $400,000 in operation would be occasioned by substituting his palliative measures for filtration. Capitalizing his various assumed savings, he figures that in the 50 year bond life, a delay of only five years in the initiation of the filtration plant will save the city $31,000,000.

Commenting first on this financial statement, it is worth noting:

1. That if, as the majority report states, the site selected is the best one, the land cannot properly be sold.
2. That an assumption that the cost of remedial measures in the watershed will save $400,000 in operation rests on an imaginary foundation. It is a fact that watershed protective methods as suggested to improve the quality of the water will cost more both for investment and maintenance than filtration.

The difficulties and cost of effectual watershed protection have not been fully realized. An investigation was made by the Department of Water Supply at the request of Comptroller Prendergast and expense estimated, as follows:

Prevention of pollution from railroad trains:		
Panning bridges	$ 16,000	
Embankments	546,000	562,000
Highway bridges		103,000
Aeration		225,000
Control of microscopic growths:		
Draining of swamps, 10 square miles at $75 per acre	480,000	
By-passing reservoirs	750,000	
Reduction of shallow flowage, 5,500,000 cubic yards at $0.25 per cubic yard	1,375,000	2,605,000
Reforestation of watershed, 11,000,000 trees		360,000
Treatment of road wash, Dikes for 925,000 feet highways	3,530,000	
Treatment of cultivated lands	1,194,000	
Land cost for marginal protecting area, 26,000 acres at $600	15,600,000	20,324,000
Total		$24,179,000

The annual fixed charge alone at 5.13 per cent is $1,240,000.

In connection with the estimated costs of protecting land, it is interesting to note that the city now owns 21,000 acres, costing $12,000,000, or $600 per acre. Of this, 12,000 acres is reservoir area, and 9,000 acres protecting and marginal area. An addition of 26,000 acres for adequate protection would not be a high estimate of the land required.

The annual taxes are now about $100,000, practically $5 per acre per year. The additional taxes on this protection land alone would amount at this rate to $130,000 per year in addition to fixed charges of $1,240,000, and with no allowance for additional maintenance.

CLEANING OF RESERVOIRS AND MAINS

In 1907 the south basin was emptied and found to be practically clean after 12 years service. Mr. D. D. Jackson reported:

> An examination of the old reservoir, south side of Central Park, was made on September 26, 1907, and in most portions of the reservoir no mud was present. In some sections there were small deposits, the largest being just south of the intake, apparently formed by an eddy at that place. Results show that it would be unnecessary to draw down the reservoir for the removal of this comparatively small amount of mud.

It is to be noted, too, that on an average the water is improved in sanitary quality by passing through the reservoirs, and through the mains. It is not improved in number of microscopic organisms, as these will grow in storage, and no reservoirs or main cleaning will materially help the water in this particular. The by-passing and covering of the reservoirs would be of assistance.

The two reports of the Advisory Commission of Engineers were submitted to the Board of Estimate early in May, 1913. On May 8, 1913, the Citizens' Union made a further protest. Passing minor criticisms of no importance, it was charged that the original report of the Board of Experts had been suppressed, and the intent of the Board misrepresented.

This accusation was submitted to the Chairman of the Board, Mr. Allen Hazen, who wrote in explanation to the Commissioner, from which I quote as follows from the *Engineers News* of May 22, 1913:

> It is in my opinion necessary to filter Croton water. It is necessary to filter it because in no other way can a supply of clean water, of good quality, worthy of the city, be secured.
>
> Filtration will do more to improve the quality of the water and protect those who use it from infections resulting from pollutions of the catchment areas than has been accomplished by all the measures of sanitary inspection and prevention of pollution of every kind that have been applied up to the present time, and that can be reasonably applied in future.
>
> It is also necessary to improve the physical characteristics of the water in order to make it acceptable for drinking water by the people of the city.

A hearing on this last phase of the matter, the desirability of filtration from the standpoint of health protection, was held by Mr. Mitchell, now Mayor. The opponents of the plan were represented by Major Cassius E. Gillette, Mr. R. Walter Cruezbar, Mr. Alexander Potter, Mr. Charles L. Parmelee, Mr. John H. Frazee.

In support of the project appeared Mr. Allen Hazen, Mr. J. Waldo Smith, Mr. Nicholas S. Hill, Jr., Col. Merritt H. Smith, Mr. George A. Johnson, Mr. George W. Fuller.

Reference was made to testimony of Mr. Fuller and of Mr. Johnson in 1909, that the Jersey City Water supply would be safe if treated with hypochlorite.

This was answered by both of these gentlemen to the effect that the 1909 testimony was based on information then available; that present information showed that hypochlorite treatment, when applied to water containing large quantities of organic matter, was of variable and uncertain efficiency; that particularly where the amount of such organic matter varied, hypochlorite application could give no safe dependence, and was not an adequate substitute for filtration.

The last chapter of this controversy was written on May 22, 1913, when Mr. Mitchell reported to the Board of Estimate his deduction that in his judgment hypochlorite would make our water safe, and that aeration would serve to remove from 50 to 75 per cent not only of the tastes and odors, but also of the color and turbidity from the water. With this he cast the vote which killed the project.

CONCLUSION

It is rather curious that a ten year long attempt to give the citizens of New York a drinking water supply of a quality such as is elsewhere demanded should have finally proven abortive. And even more curious that the same officials who had voted to give New York a proper drinking water should later with the same information before them reverse themselves, that a Board of Aldermen, who but a short time before were considerng a vote of censure on the executive department for their slowness in providing filtered water should a few months later repeal their ordinance and condemn the project; that the newspapers which had just stopped printing attacks on the city officers for their negligence in furnishing bad water, should write to oppose the so-called steal when they were about to receive their demands.

The various phases of this matter have been clearly before the city officials for many years. It has never been represented as absolutely imperative. Neither is it imperative for the city to clean its streets daily, to maintain good smooth pavements, or to build a $15,000,000 office building. But it is certainly desirable that a city of the rank of ours should have a pride in doing these things; and it should have a pride in drinking a water for which it need not apologize as reasonably safe, at most times, and fairly decent looking at most times.

Real safety we are not getting. Limited by the need of adding only enough hypochlorite not to spoil the taste, and with an organic content in the water varying from day to day, it is not physically possible closely to vary the hypochlorite dose so as to oxidize both the organic matter and the bacterial content and leave no objectionable excess. And conditions may arise at any time when the hypochlorite treatment will not be effectual in preventing the transmission of disease.

From an aesthetic viewpoint, our water is much of the time unobjectionable, but with turbidity running at times as high as 100 parts per million, color 60 parts per million, and sufficient microscopic organism to give unpleasant tastes and odors, our water supply is far from being a source of civic satisfaction.

This is not before the public as an engineering question. A comparison of the engineers mentioned above approving of the project with the list of those who have opposed, is convincing.

As a question of expediency, when a vote for $100,000,000 for good roads, which means an annual charge alone to the people of this city for interest and repairs of $5,000,000, in addition to the cost to the upstate population, is carried without hesitation, it is hard to understand a reluctance to spend $8,000,000 for drinking water. For maintenance and operation the cost to those served is but about 25 cents per capita per year, much less than is now the cost of bottled water to the public.

When this question comes up for final settlement, and no settlement is final until it is right, it is to be hoped that the legislative authorities will consider the question in all its aspects; and after they have satisfied themselves, and have appropriated the necessary funds, that they will leave the execution of the project in the hands of their engineers, to give the city a water supply which, instead of being at best not immediately dangerous, will be up to the standard maintained by ordinarily progressive communities.

The writer takes pleasure in acknowledging his indebtedness for data furnished, to Mr. I. M. deVarona, Chief Engineer, Mr. E. G. Manahan, Division Engineer, and Mr. Frank E. Hale, Director of Laboratories, all of the Department of Water Supply, and for assistance in writing this paper, to Mr. Charles B. Buerger, formerly in charge of design of the Jerome Park Filters.

DISCUSSION

Mr. D. W. French: Having heard but a small part of Mr. Fuller's paper, am sure there is nothing the speaker can say that will be of interest or that would have any bearing in this particular project.

The filtering of public water supplies is a subject that we are all interested in and is getting to be quite the proper caper.

The Hackensack Water Company are now filtering from 28,000,000 to 30,000,000 gallons per day, the plant has been in operation for nine years, and our Company do not feel that they ever made a move which met with so much satisfaction and popular approval as when it decided to filter the entire water supply.

We have felt very thankful since, that the movement was a voluntary one on our part, and not one into which we had been forced by public clamor, due to a typhoid fever outbreak.

The cost of filtering on the Hackensack system compares favorably with what is being done at other plants where a like quantity, and quality of water is being treated, but regardless of the plant or the amount of water being filtered daily, or the cost of filtering per million gallons, if the quality of filtered water is such that the company or municipality supplying it feel that there is no reasonable possibility of typhoid resulting from its use, then to my mind, filtering of any supply is worth all that it costs, or in other words, it is cheap at any price.

Dr. Wm. P. Mason: Mr. President: Side-stepping the matter to which you refer, let me say that in Troy we have no filtration, not because we do not believe in it, but because we have not the wherewithall to pay for the same. There is no question whatever but that Mr. Diven and the rest of us would like to see a filter plant in Troy and we all believe that we are going to have one, but Mr. Diven does not mention the date. Our cash is a little short at the present because we have other things to attend to, among them the present pipe line. It runs only part of the way to the city, and it is old and full of holes and it leaks, in fact it sprinkles a good part of the county, but we are in hopes that it will stay together sufficiently long to let us get a new one. We are very firm believers in filtration up our way. We have had designs made for a plant; they are on paper and old enough to be somewhat improved today if we should see any money in sight. Just at present we are believers rather than practicers only because we haven't the cash to put into a plant which we sadly need.

Mr. J. M. Diven: Dr. Mason says Troy cannot at present afford a filter plant; but, can it afford not to have one? Of course, there must be the water to filter, and it is difficult some times to get that through a county wide "automatic sprinkler line." But the new pipe line is authorized, and the filter plant should be. Dr. Mason, doubtless, drinks bottled water, as do most of the well to do citizens of Troy, but the less fortunate have to drink such water as the city furnishes, and this should by all means be the very best possible to supply to them. The bottled water consumed in Troy costs its citizens a considerable sum of money each year; have heard it estimated at $75,000 per annum, more than enough to pay interest on cost and depreciation on a filter plant and the cost of operation. Pure water should not be a matter of dollars and cents, it is a necessity and should be supplied at almost any cost.

It is a matter greatly to be regretted that two such important and influential bodies as the water commissioners of the greatest city in our land and the conservation commission of the leading state of the union should take such decidedly retrograde action as, the one stating that filters were not needed, as the water was good enough as it is; the other that permission should not be given to the city of New York to acquire additional water rights and lands for their preservation and protection to insure a water supply for the future. There is no "good enough" in water, even the very best must fail of perfection in some essential, but no effort should be missed to have the best possible under existing local conditions. The contention that only immediate or even near future supplies should be provided for is ridiculous and so great a body as the New York State Conservation Commission should be ashamed to have taken such a stand. It is the plain duty of all municipalities or water companies to secure, and secure *now* all the available water rights and water sheds that might at any time be utilized in improving and extending its water supply. Get these rights and lands first; for when taken up for power or other purposes it will be difficult and expensive to acquire them. One would think that the city of New York had already had sufficient experience of this kind. The lands and water rights acquired need not be now taken from industrial uses, but can be leased for any purpose that they might be useful for, but should first of all be available for the water supply of the city when needed, and so disposed of that they can be converted to city uses without long and tedious, not to mention expensive, legal proceedings, when needed; proceedings that might long delay a much needed additional water supply.

The example of two such influential bodies, examples that are apt to be copied or used as a precedent by others, is greatly to be regretted on account of the wide influence that it may have.

MR. NICHOLAS S. HILL, JR.: The speaker heartily concurs in all that Mr. Fuller has said, he is rather glad of the opportunity to say for the Second Commission that it was unfortunate for it that they were not able to bring in a unanimous report on the question of the advisability of filtering the Croton water. One member of that Commission, however, had a conviction, and he could not see the immediate necessity of filtration, although he admitted that such a necessity might arise in the future. The majority of the Commission was satisfied that the present treatment with hypochlorite of lime was not sufficient to safeguard the supply. The wording of our report was that immediate filtration of the Croton water was highly advisable, although not imperative. We felt that this statement truly expressed the situation in the City of New York.

The typhoid fever death rate does not indicate the presence of endemic typhoid conditions. In fact, the typhoid death rate is less than the average. We were fully aware of the potential danger of an epidemic which may arise at any time if conditions on the watershed are ripe. In view of the tremendous population using the Croton water, this supply is a greater potential source of infection than any other single medium in existence, and we felt that if an epidemic did occur it might be of more alarming proportions than any hitherto known.

The Commission, moreover, felt that the physical quality of the Croton water did not measure up to the standards of the water supplies of other large cities of the United States and that filtration was justified on account of the high color and turbidity which are present at times and due to the offensive odors which exist at certain seasons of the year as a result of microscopic growths in the reservoirs. We felt, at least the majority did, that while the situation was not an imperative one in which danger was imminent, it was highly advisable to filter the water and to commence filtration operations at as early a date as possible.

In view of the fact that our Commission was requested to investigate alleged defects in the plans and specifications for the proposed Jerome Park filters, it gives me pleasure to say that we were unanimous in reporting that the site chosen for the filtration plant was the best location; that mechanical filtration as recommended by the consulting engineers was best suited to the needs of the Croton water; that the detail design and general construction of the filter plant as proposed were in accord with modern practice and were well and carefully executed, and that the specifications were reasonable and sufficient.

Dr. Frank E. Hale: The question of filtration has come up and been turned down. Filtration probably will come when the people demand it.

In lieu of filtration, we might run rapidly over the various means which are taken to protect the Croton supply. In the first place there is continual inspection by the Sanitary Division under Messrs. Coffin and Culyer. There are regular trips over the various watersheds, streams, reservoirs, etc., to observe physical signs of pollution, and these are abated.

Every case of typhoid fever on the watershed is recorded and carefully looked after. Disinfectants are furnished and if necessary the cases are removed to the hopsitals. All trains in passing over the watershed have their toilets locked during transit. Bridges over the reservoirs and streams are swept daily to remove the horse droppings, etc.

At several points on the watershed the sewage is treated and besides at several small places chlorination is used. There is a disposal plant at Brewsters with subsoil irrigation. At Mount Kisco there is an entire sewage disposal plant, comprised of a septic tank, contact beds, sedimentation and filtration beds, followed by chlorination, and the raw sewage goes through the plant and comes out as clear as crystal and at times safe to drink.

In the Laboratory Division samples are taken weekly from the various sources of the supply and analyzed and also daily from the supply as it leaves Croton Lake, as it arrives at the city at 135th street, and further down in the city at City Hall. Between Croton Lake and the city, at Dunwoodie, the whole Croton supply is continuously chlorinated.

Probably the greatest trouble we have with the Croton water is the taste and odor coming from microscopic organisms. We try to avoid this by drawing the water at a depth wherever possible and by treatment locally with copper sulphate. The speaker might say that the reservoirs are so deep that amounts are figured on the top 10 feet only in treating the water. We have also tried the last couple of years to improve the supply by drawing from Croton Lake at depths, in 1912 about 50 feet below the surface, and during the last year about 75 feet below the surface.

During 1912 the thermocline of which Mr. Fuller spoke was some 15 to 20 feet below the surface. During last summer there were two thermoclines, one about 20 to 25 feet and the second at 90 feet.

Below 90 feet the water has been completely stagnant, but above 90 feet the draft at a depth has kept the water in circulation.

Here are a few figures to show what the effect of drawing at a depth has upon the supply: In 1911 the temperature during the months of July, August and September at 135th Street, that is, of the water as it reached the city, was 72°; in 1912 it was 67°; and in 1913, 65°. The improvement during these three months was 7°. At times the water was at least 10° cooler than in previous years.

The number of microscopic organisms in the water at 135th Street in 1911 was 2836; in 1912, 1072; and in 1913, 677; in other words, less than 25 per cent of what it was two years previously. That this is due to drawing the water from the bottom is shown from the figures taken at Croton Lake. The surface of Croton Lake in 1913 had 1405 organisms against the 677 in the water at 135th Street. The samples taken in the screen chamber of the gate house where the water is just starting for the city contained 635 as compared with 677 organisms at 135th Street, showing that this benefit did come from drawing the water at a depth.

The treatment of the supply with chlorine at Dunwoodie seems to have been quite effective during the last year. As the water left the gate house at Croton Lake there was an average of 7 per cent in 0.1 cc., 23 per cent in 1 cc. and 59 per cent in 10 cc. tests for B. coli. When it reached the city it contained 0 per cent in .1 cc.; 3 per cent in 1 cc.; and 23 per cent in 10 cc. Comparing the tests by multiplying the 0.1 cc. tests by 100, the 1 cc. tests by 10, and adding to the 10 cc. tests, there was 95 per cent removal of B. coli. In the same way during 1912 there was 90 per cent removal of B. coli. This reduction was probably caused chiefly by the chlorine treatment.

MR. HAZEN: It is apparent that the filtration of the Croton water is primarily a question of giving clean decent water. The sanitary side of the question is not the dominating one at the present time.

JAMES M. CAIRD (by letter): This paper by Mr. Fuller is most interesting as it deals with the large amount of detail sanitary work which is being carried on to protect the quality of the New York City water supply.

The fact is also noted, that notwithstanding all of these excellent methods of treatment and patrol the quality of the water is still such that it should be considered suspicious.

Conditions in this country are becoming such that the time is not far distant when all surface waters will have to be filtered, as is the case in some foreign countries.

It has been repeatedly shown that even with the most elaborate system of inspection of the watershed it is at times impossible to exclude dangerous pollution, which is eventually followed by epidemics.

It is surely wise to maintain a water as free from pollution as possible so that when it is filtered results cannot help being highly satisfactory.

The public judge the quality of a water by its appearance and so long as the water is free from color and turbidity, they are satisfied.

The use of some spring waters which are satisfactory in appearance is some times very dangerous.

A large percentage of the population are unable to purchase spring water, and these certainly should be supplied with pure water.

Hotels and some other buildings have filtration plants, but why should not the entire population be served with pure water?

It is certainly strange that the installation of a filter plant should be delayed when it is considered that its installation and operation would cost about 25 cents per year per capita, equal to about 2 cents per month. When it is considered how much improvement in general health would follow the use of a strictly pure water this would more than offset the small cost.

With a municipal filter plant in proper operation, the use of individual filters would cease and all manufacturers, which require pure water, would also save money.

While the typhoid fever death rate is not high when compared with American cities, yet it is much higher than in some foreign cities where the water supply is properly filtered.

It is not the intention to convey the idea that all of the typhoid fever is due to the water, but an improved water supply would certainly cause an improvement in the general health and therefore less chance of contracting typhoid from sources other than water.

If this supply was furnished by a corporation how long would the public stand for a water containing a turbidity as high as 100 parts per million; color 10 to 65 parts per million; bacteria 5 to 1200 per cubic centimeter (agar counts twenty-four hours at 37.5° C.) not to mention the odor and taste due to algae?

Filtration will remove some of the odor and taste due to algae as will also aeration but unless the algae are killed by treatment they will cause serious trouble in operating any filter plant as well as great expense.

Mention is made that the water in the reservoir, at times, is treated with copper sulphate to kill the algae. The dose being calculated for a depth of 10 feet, but no mention of the strength of this dose is made.

Dr. Hale shows that B. Coli-communis is present in 3 per cent of the 1 cc. samples, after the water has been treated with chlorine.

Until the filtration plant is installed and in operation would it not be a good plan to apply an overdose of the chlorine to remove all B. coli. and then remove the excess of chlorine by the addition of sodium thio-sulphate applied at another location?

It is not the writer's intention to convey the idea that this water should not be filtered, but that more chlorine should be used to make the best of a doubtful case.

The estimated amount of sulphate of alumina required to treat the New York water (average 1 grain, maximum 2 grains per gallon) seems very generous.

At Harrisburg, Pa., where the length of the coagulation period is about the same as proposed for New York City, the average amount of sulphate of alumina used during the past year was 0.79 grains per gallon. The average turbidity was 56 with a maximum of 970 parts per million.

Of late it has been quite noticeable that about all expert commissions have advised mechanical filtration as the best and cheapest method of water purification.

The decision no doubt being due to the fact that this method will produce a water free from color and turbidity as well as from bacteria.

It is impossible to furnish a water free from color and turbidity with slow sand filters unless a coagulant is used, and this increases the cost of operation.

The delay in installing the New York City filtration plant seems to be a step backwards.

Mr. George A. Johnson (By letter): It was with great regret that the writer was obliged to be away from the city on the day of the first meeting of the New York Section of the American Water Works Association, for he wished to discuss Mr. Fuller's paper orally, and in other ways to further the interests of the new section so far as lay in his power to do.

The question of filtration of the Croton water supply, which Mr.

Fuller has covered so thoroughly, is one of immense importance to the welfare of New York and is one which seems to be but indifferently understood except by those who have come in immediate contact with it, and have followed it through the years that have passed. A great many people hold the view that the Croton water does not require filtration, and "point with pride" to the low typhoid fever rate as proof that it does not. It is true that New York City has one of the lowest typhoid fever death rates of any city in this country, but it is equally true that this death rate today is three times that of many large European cities. The difference in the typhoid death rates in New York City and in the European cities referred to means a loss to New York of some 300 lives per annum, and a modest estimate of the value of these lives, and the cost of treatment of the ten-fold number of cases where the patient recovers, represents a loss of vital capital to New York of some $2,000,000 annually in excess of that which would be lost were the typhoid death rate as low as it is in Berlin, Hamburg, Vienna, London and some other large European cities.

Those who have most to do with deciding whether or not New York shall have a filtered public water supply are men who know very little about the real character of the Croton water. In their city offices they have spring water, and in their homes they are supplied with either spring or filtered water. There is no first-class hotel in the city of New York which does not either supply spring water to its guests, or which does not maintain a filter. Consequently, not having to drink the water as drawn direct from the spigot, as the majority of the citizens of New York are obliged to do for reasons of economy, it is hard for them to realize that the water supply of this city is not the best in the world. The plain facts are that among all of the large cities of this country and western Europe, the water supply of New York at the present time is undoubtedly in many respects as bad as the worst, and very probably in some respects the worst of them all.

Of the physical defects of the Croton supply much could be said. Many of us know that during certain months of the year the water possesses an exceedingly offensive odor and taste, and is disagreeable to look upon. The writer lived for a number of years at the corner of 92d Street and Central Park West, and has no difficulty in recalling the fact that for weeks at a time the water as drawn from the spigot for drinking purposes and set away in the refrigerator to cool, if allowed to stand over Sunday developed such an offensive taste and odor that it could not be so used. He also recalls the fact that the bad water was frequently covered with a green slime, and only the happy coincidence that he had a shower bath at hand prevented his emerging from the bath covered with this slime and smelling like a fish.

Ninety-second Street is immediately opposite the reservoir, and this body of water is used as a playground for seagulls. It is the custom of seagulls, as is well known, to obtain their food from the discharge of sewers around the water front. Is it not proper, therefore, to compare in some measure the habits of the seagull to those of the common house fly? In other words, is it not possible for the seagull to obtain infectious matter from the sewers along the water front, and carry such matter to and deposit it in the reservoir? The writer distinctly recalls the efforts of the watchman to prevent the daily aquatic sports of the seagull in the reservoir, in which endeavors he daily wastes a great deal of gunpowder. Since there is a fine of $25 for actually killing a seagull, it follows that the watchman uses no shot.

This last thought brings the writer back to conditions which exist in Bombay, India, where, on a nearby hill, are located the famous Towers of Silence, wherein are given to the vultures the bodies of the dead Parsees. The writer has viewed the ceremony of disposal of the dead in this way, and has observed the vultures flying away with long sections of intestines and other portions of the dead bodies. Apparently no exception is made of people dead of cholera or other infectious disease, all of them being disposed of in this same manner. Accordingly, it was necessary for the city officials of Bombay to cover all parts of their filter plant, and all of their distributing reservoirs, so that the water once it entered the purification plant should not be again exposed until drawn from the faucet; otherwise, if the filters and reservoirs were left open there was every possibility of gross contamination of the water being caused by the vultures dropping parts of infected bodies into it in their flight.

An important feature favoring the filtration of the Croton supply is the widespread use of spring water in New York City. In order to get some line on how extensive this industry is the speaker caused to have made a canvass of the offices in his office building. This canvass disclosed the fact that over one-half of the offices use spring water at a total annual cost of over $2000 a year. If we assume, as we well may, that all office buildings in New York follow this example, and that many hotels, apartment houses and private residences do likewise, the annual cost of spring water consumed in the city of New York, largely because of the unsatisfactory quality of the existing public water supply, will run into the millions.

Some of the most prominent opponents of filtration of the Croton supply hold the view that the sterilization thereof with hypochlorites is a sufficient treatment. It is certainly strange, in view of the mass of literature bearing on this subject, which has appeared in recent years, that the advocates of this method of water purification have not learned that the hypochlorite treatment, while very valuable in emergencies for checking typhoid fever epidemics emanating from impure water, can only be considered in the final analysis as an adjunct to filtration. Particularly is this true where the water supply possesses marked physical defects, such as are characteristic of the Croton supply.

In the treatment of unfiltered water with hypochlorites it is necessary to use larger quantities of the germicide than when treating filtered water. In the endeavor to effect complete sterilization this often leads to the use of quantities of the chemical in excess of those which the water can absorb, and an exceedingly offensive taste and odor is imparted to the treated water. Not a few large cities have reversed their former judgment that the hypochlorite treatment would be sufficient, this decision in no small measure being due to difficulties actually experienced from tastes and odors of the chemical when used in the quantities considered necessary to produce adequate sterilization. Cleveland, Ohio, now designing a filtration plant, is one of these, and Jersey City, New Jersey, is rapidly approaching the day when mere sterilization of the impounded water supply with hypochlorites will prove unsatisfactory, and filtration be resorted to. At Trenton, New Jersey, where the relatively high typhoid fever death rate was markedly reduced by means of water sterilization with hypochlorites, a filter plant is nearing completion; and since the inauguration there of the hypochlorite treatment of the raw Delaware River water numerous well-founded complaints have been recorded because of the offensive taste imparted to the water when it became necessary to use large amounts of the chemical in order to sterilize the water when in its worst condition.

As early as 1910, in an address made before the Annual Convention of the American Public Health Association, held in Milwaukee, Wisconsin, the writer set forth in considerable detail certain limitations of the hypochlorite treatment of water. His closing statements, all of which have been substantiated by actual experience in many cities during the past three years, were as follows:

> In making a complete analysis of the practicability of this process, it is necessary to recognize the fact that it is not possible by the use of this germicide to overcome certain disadvantages, such as the following, which do not appear in connection with certain styles of water treatment:
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> 1. Inability to remove or destroy all of the spore-forming bacteria not considered to be pathogenic to man, at least, not those common to water.
> 2. Inability to remove bacteria which are embedded in particles of suspended matter.
> 3. Inability to remove turbidity.
> 4. Inability to remove appreciable amounts of color or dissolved vegetable stain.
> 5. Inability appreciably to remove organic matter.
> 6. Inability to remove swamp tastes or odors.
> 7. Inability to remove creosote tastes or odors coming from the cleaning of stills used in the destructive distillation of wood.
> 8. Inability to soften water; as a matter of fact, the addition of hypochlorite of lime usually results in a slight increase in the hardness of the water, although this is not ordinarily measurable, notwithstanding the fact that the commercial product usually contains a little free quicklime which reduces slightly the carbonic acid in the water.
> 9. Difficulties encountered in applying this process, except with the greatest care, to waters which contain substantial quantities of reducing agents or compounds capable of oxidation, such as nitrites and unoxidized iron.
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> The foregoing statements set forth the advantages and shortcomings of this process which, like other things that are new, is likely to be, and in some cases is, considered a cure-all for all water ills, no doubt with disappointing results in some cases.
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> The application of hypochlorite to water, while comparatively simple, should always be carried out with much care and fidelity by a competent analyst; otherwise, if the dose is not adjusted so as to meet satisfactorily all local conditions, there is liable to be alternately an underdose of the chemical insufficient to sterilize or an overdose which will result in objectionable tastes and odors readily noticeable to the consumers, and due to the bleach itself.
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> The use of hypochlorites cannot be considered in the light of a substitute for filtration. Where waters are uniformly satisfactory in appearance, but open to suspicion as regards their content in bacteria, the use of the hypochlorite process alone in many cases may prove sufficient. Where waters are unsatisfactory in physical appearance and are also polluted and require filtration, the combined use of filters and the hypochlorite process is called for. As an adjunct to filtration processes it has a distinct field of applicability, as hereinbefore stated, for at a moderate cost it is feasible to obtain a water which is practically above suspicion; and, furthermore, there is brought about a substantial economy in the first cost of the filtration plant. This is made

possible by the use of higher rates of filtration than are ordinarily used, and the required filter area may therefore be reduced. It also effects a substantial economy in the cost of operation.

This is an age when people are demanding the best water supply obtainable. Twenty-five years ago only 300,000 people were supplied with filtered water in this country, while at this time over one-third of the urban population of the United States is supplied with water so purified. Public sentiment now demands that water supplies shall not only be free of disease germs, but that they also shall be clear, colorless, soft and free from objectionable tastes and odors. Almost all of the large inland cities have filter plants, or are building them. Of all the large Atlantic seaboard cities New York stands forth preëminently in the unenviable light of being too poor or too unwise to provide such a plant. For a city which controls 46 per cent of the commerce of the United States this assuredly is not a commendable position.

NOTE: This paper is open for discussion at the 34th annual convention, Philadelphia, Pennsylvania, May 11–15, 1914, and the discussion on it at that time, also any written discussion, will be printed in the next issue of the JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION.